Making Antimatter Matter:

Online Outreach at the

Centre for Antimatter-Matter Studies

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Declaration

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma at any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except when due reference is made in the text.

David Harcourt

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Abstract

This thesis describes the design and construction of a science communication artefact, in the form of a fully-functional public website, which was commissioned by the Australian Research Council Centre of Excellence for Antimatter-Matter Studies (CAMS).

The website's purpose is to inform the public about antimatter, and also to be the public face of CAMS, representing CAMS' own research and activities to the non-scientific community.

The process of interviewing stakeholders, writing text, selecting illustrations and obtaining permission from copyright holders, liaising with artists and animators to produce original artwork and animation, as well as building and activating the website, forms a significant part of the work involved in this project.

In addition, this thesis reviews the literature about the history and theory of science communication, and about effective writing for the Internet.

In order to put the project into context, the thesis reviews some other science communication websites which contain material related to antimatter, as well as the online public outreach of CAMS' own peer organisations: other Australian Research Council Centres of Excellence.

The thesis makes recommendations about potential future development and expansion of the website, and about evaluation of its communication.

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CAMS	The Centre for Antimatter-Matter Studies (see page 1)
CERN	The European Organisation for Nuclear Research
CPAS	The Centre for the Public Awareness of Science, at the Australian National University
PET	Positron Emission Tomography (see "Nuclear medicine", page 3)

1 Introduction

1.1 This thesis

This thesis describes the design, construction and implementation of a science communication artefact.

The Centre for Antimatter-Matter Studies commissioned me to create a new website, as an adjunct to its existing site. This new site is intended to be an awareness-raising and educational resource, to inform the general public about antimatter.

1.2 The author

My background relevant to the project is mentioned here in order to establish a context for those occasions where my own opinions have been included in this thesis. I have an honours degree in physics and astronomy, which provided the background in physics required for this project. I also have several years' professional web development experience, and have studied science communication, including modules in web design and in communicating science with the public, at postgraduate level at the Australian National University.

1.3 The Centre for Antimatter-Matter Studies

The Centre for Antimatter-Matter Studies (CAMS) was founded in 2005, and is an Australian Research Council Centre of Excellence. Its aim is to develop tools and techniques to research positron and electron interactions in the chemical, physical and biological sciences.

CAMS has nodes throughout Australia, including the Australian National University, Flinders, Curtin, James Cook and Charles Darwin Universities, the University of Western Australia, the University of Adelaide and the Australian Nuclear Science and Technology Organisation.

CAMS also has collaborative partners in Europe, the USA and Japan (ARC Centre of Excellence for Antimatter-Matter Studies, p. 7).

1.4 Research at the Centre for Antimatter-Matter Studies

Researchers at CAMS study the interactions of positrons and electrons with atoms, molecules and materials, to gain a better understanding of antimatter and the way it interacts with matter. This research has a wide range of practical applications, from nanomaterials to biology and medicine.

1.5 What is antimatter?

Everything we are familiar with in our world is made of matter, not antimatter. Ordinary matter is made up (normally) of atoms, and atoms in turn can be broken down into subatomic particles: for example protons, neutrons and electrons.

For (almost) every subatomic particle there exists an equivalent antiparticle. For the proton there is the antiproton, for the neutron there is the antineutron, for the electron there is the positron, and so on.

These antiparticles have properties that are similar to, but also opposite to, their corresponding positive matter particle. They have the same mass, but an exactly opposite electrical charge.

When a particle and its antiparticle come into contact with one another, they annihilate: all their combined mass is converted into energy (Buckman, 2008).

1.6 Why study antimatter?

Fundamental research is an end in itself. However, a public outreach project such as this has to consider its audience's point of view. "Blue-sky" research, which may or may not provide tangible benefits at some point in the future, is likely to be of less interest to a general audience than science which can be used for a practical purpose. Fundamental sub-atomic physics is also likely to be less comprehensible, and therefore less immediately appealing, to a lay audience.

Fortunately for CAMS' public outreach, antimatter research has a number of practical applications which are very relevant to daily life.

1.7 Some practical applications of antimatter research

1.7.1 Materials science

Antimatter can be used as a tool to investigate the structure of materials. Injecting positrons into a material, and then detecting their annihilation with electrons within the material, can reveal the material's structure at the nanometre scale. This can provide useful information about, for example, the material's porosity and electrical conductivity. It can also help to show up areas where material is becoming worn or degraded, long before they are visible to the human eye.

Many nanomaterials have been engineered, using positrons, to possess specific properties. This includes specialised materials, such as slow-release membranes for pharmaceuticals and fertilisers, as well as everyday objects like plastic food wrapping (Buckman, 2008).

1.7.2 Nuclear medicine

Positron Emission Tomography (PET) is in use as a diagnostic tool in hospitals around the World. It relies on introducing into the body a radiopharmaceutical which emits positrons, and then detecting where and when the positrons annihilate with electrons in the body. A PET scan can produce three-dimensional images of the inside of a living body. It can detect diseases, highlight brain function, and show how all the body's internal organs are working. The PET procedure is less invasive than other techniques, but it can build a detailed picture of a patient's health: A PET scan can be accurate to within a few millimetres.

Antimatter is essential to a PET scan, and the procedure is well established, but the sub-atomic process that occurs between the moment when the radiopharmaceutical emits a positron, and the moment when the positron annihilates with an electron, is still not completely understood.

CAMS is currently researching this process, in the hope of producing more-accurate PET scans, and lower-dose radiopharmaceuticals (Buckman, 2008).

1.8 Why tell the public about antimatter?

Anecdotal evidence suggests that many lay people associate antimatter, and nuclear physics in general, with bombs and little else. Dispelling some misconceptions about antimatter can only be to CAMS' advantage, and to the advantage of scientific research in general.

As will be discussed below, science itself cannot flourish in an atmosphere of fear and suspicion; nor should it be controlled by an elite. If the public is to make good democratic decisions about science, it's necessary for the electorate to understand the issues. This cannot happen unless the public has access to accurate, intelligible information.

As well as political benefits, there are cultural benefits to be gained from a well-informed, engaged public. Science is a part of human culture, as much as literature or music, and should be available to all members of society.

Publicly-funded researchers in particular have a duty to make their work accessible to the society that supports it. As an Australian Research Council Centre of Excellence, CAMS has an obligation to conduct outreach activities. This project is a part of CAMS' outreach.

1.9 Current communication by the Centre for Antimatter-Matter Studies

All CAMS' communication is professional and of high quality. It shows good organisation and attention to detail, which reflects well on the management, on CAMS' sponsors, and on any other research facilities which choose to associate themselves with CAMS.

CAMS' research is depicted in scientific detail, on the current website (ARC Centre of Excellence for Antimatter-Matter Studies) and in the annual report (ARC Centre of Excellence for Antimatter-Matter Studies, 2006) (ARC Centre of Excellence for Antimatter-Matter Studies, 2007).

1.9.1 CAMS' communication with other specialists

CAMS' main communication medium with the physics community is the publication of journal articles. The publication of articles in peer-reviewed journals is a highly specialised skill, entirely different from communication with the public.

CAMS' communication with funding bodies, colleges, government and NGOs is excellent, but again, this is a specialised form of communication with its own goals and strategies.

This thesis will therefore not concern itself with communication with the physics community or with institutions, but will concentrate on educational communication with the public.

1.9.2 CAMS' current communication with the public

At our initial meeting, CAMS' Chief Operations Officer and Research Director both stated that CAMS is keen to educate the public about antimatter, but that they are aware that CAMS has not yet really addressed the issue.

In addition to the technical information aimed at physicists, there are a few pages in CAMS' annual report, and on CAMS' existing website, explaining some of the basics of antimatter. However, these pages still assume a great deal of knowledge on the part of the reader (ARC Centre of Excellence for Antimatter-Matter Studies, 2006, pp. 2-3) (ARC Centre of Excellence for Antimatter-Matter Studies, 2007, pp. 1-4) (ARC Centre of Excellence for Antimatter-Matter Studies). The quality of the writing is good, but the material has clearly been written by a professional physicist, with (perhaps unintentionally) a scientifically-educated audience in mind. A few high-school and university students might have this level of knowledge, but it cannot be assumed to be general knowledge outside the physics community.

1.10 Purpose of the project

To date, CAMS has done little direct communication with the public, but CAMS' management has begun to address the issue. Because CAMS currently has so little material suitable for the public, a modest investment in the area has the potential to lead to significant improvement.

As part of the initial consultation involved in this thesis, I worked with CAMS to identify two key methods through which CAMS could effectively communicate with the public: a series of public lectures (with an evaluation tool to aid in their continual improvement) and a new, public website. This thesis touches upon the public lectures (as they played a part in developing the website), but really deals only with the development of the new CAMS website.

The purpose of the current project was to construct a website which would inform the public about antimatter, taking into account the client's specific wishes and requirements, and with attention to the current best practices in science communication. Evaluation of the communication material's effectiveness was considered by the client to be beyond the resources and timeline of the commission.

1.11 Overview of the thesis

In our initial meetings, CAMS' Chief Operations Officer, CAMS' Research Director and I established that the highest-level, strategic communication goals of their commissioned project were:

- to link the fundamental research with the real-world applications;
- to raise the profile of CAMS with the public

- to create an informative website in accordance with current best practices in science communication

This thesis describes the process of designing and creating an artefact intended to achieve those aims.

It begins by describing the background to the project:

- the advantages and disadvantages of this type of artefact, and their design implications;
- an overview of the methods used;
- the significance of this project.

It reviews the literature about science communication, to show its relevance to modern society, and to show that science communication (as opposed to other branches of communication) presents its own particular challenges.

It reviews the literature about web-based communication, to establish current ideas about best practice.

In order to put the project into context, the thesis reviews some other science communication websites which contain material related to antimatter, as well as the online public outreach of CAMS' peer organisations: other Australian Research Council Centres of Excellence.

It then describes the information-gathering process, and the development of the communication material.

It describes some of the difficulties in obtaining feedback from the target audience, and makes suggestions for future development of the artefact.

Note that this is not a conventional thesis, in that it doesn't describe a standard piece of research. The process of developing and constructing the artefact was an integral part of the project, and represents a significant proportion of the effort involved. Given that it was necessary to:

- interview stakeholders to agree the content;
- compose original text;
- select illustrations and obtain permission from the copyright holders;
- liaise with artists and animators to produce original artwork and animation;
- construct and activate the website;

in consultation with the client it was decided that, due to time and resource constraints, evaluation of the communication was outside the scope of this project.

2 Background to the study

2.1 Advantages of a website rather than a lecture or book

2.1.1 A larger audience than a series of lectures

Internet use is popular and growing: According to internetworldstats.com, world Internet use has increased from 16 million users in 1995 to 1,464 million users in 2008 (internetworldstats.com). This is already more than 20 per cent of the total world population. An Internet site has the potential to reach a much larger audience than any number of lectures.

A public lecture requires each audience member to travel to a given venue, at a specific date and time. By contrast, the Internet is available globally, twenty-four hours a day, so the information is available wherever and whenever the user chooses. Requiring less investment on the part of the audience is likely to increase the initial size of the audience. How many of these audience members will stay to read on is a separate issue, largely determined by the structure and content of the communication material, but the Internet can deliver a larger *potential* audience than any other medium.

2.1.2 A wider audience than a lecture or a book

Good links to the website can draw in a reader who might never browse the relevant section of a bookshop.

Many people without a scientific education might be intimidated by the idea of a public lecture on antimatter. A website can reach people who wouldn't think of attending a real-world event.

Internet use is effectively free, so a website can attract readers who wouldn't buy the book (or know which book to buy).

2.1.3 Word-of-mouth recommendations can be immediately effective

Even if every audience member leaves a lecture enthused, and recommends the lecture to others, potential new audience members will have to wait for the next local performance (if any) of the lecture, whereas a satisfied visitor to a website can pass on the website's address to their friends, and each contact can immediately access the site.

2.1.4 A website can be updated continually and quickly

The website includes a survey section where readers can leave feedback and ask questions. While there is no intention at present to answer questions in anything like real time, it will be possible to add new topics or explanations to the site in response to frequently asked questions, if the site's administrators choose to do so. Simply adding a new page, tab or pop-up need not affect the rest of the site, and can be achieved at little cost or inconvenience.

With printed material, this would be a much more expensive process. Modifying a lecture would also be more time-consuming due to the extra rehearsal involved, and because of the risk of the new material interrupting the narrative flow.

2.1.5 Interactivity

In a lecture the audience must experience the information at a fixed pace, in a fixed order. If the material is complex, and largely new to the audience, a momentary lapse of attention can result in the audience losing the thread of the communication, or simply becoming overwhelmed. Of course, any well-structured communication material (whether website, book or lecture) will contain sub-headings and other indicators of the material's structure and direction, but these will always be easier to follow in a written rather than a spoken form.

On a website, users can return to review sections of the material as often as they wish. Each time a technical term is used, a hyperlink can be provided to its definition, and the user can choose on each occasion whether or not to follow the link.

2.1.6 Animation

Animation has the potential to illustrate complex processes more clearly than a series of static illustrations, and more succinctly than a verbal description. It's beyond the scope of this project to produce a fully animated website, but I have commissioned three original animated diagrams, and suggested to the client a few other instances where animation could be used to good effect.

2.2 *Disadvantages of a website*

2.2.1 Internet access isn't universal

Even in the developed world, Internet access is still not universal, so placing information on a website could be seen as excluding a certain section of the population, due either to lack of Internet access or lack of computer literacy. However, as discussed above, no medium is universal, especially when it comes to conveying scientific information which many members of the potential audience may consider to be obscure, or irrelevant to their lives. It can be argued that the huge and increasing size of the Internet audience offers the best chance of reaching the maximum number of people.

2.2.2 Interactivity can be taken too far

A website is clearly more interactive than a lecture. The user can follow links at will, and pick and choose the sections which appear the most interesting, but this is effectively no different from flicking through a book in a random order. When teaching something complicated such as antimatter, it might in fact be better to impose (or at least suggest) a specific order in which to approach the various topics.

There is a debate in science communication about to what extent the communication process should be driven by scientists, and their ideas about what the public ought to know, and to what extent by the public, and their interest in specific information. (See "In defence of the Deficit Model", page 30, below.) A structured but modular website is a reasonable compromise between these two poles.

2.2.3 This site might disappear among similar sites

It's increasingly easy for anyone to set up a website, and today's web users are aware that not all sites contain reliable information. For this reason, it's no longer sufficient for a website simply to provide information. The site's designers must consider how to establish credibility with the reader.

An analysis of users' comments about various types of informative website found that "in 13.8% of the comments, users referred to advertising, usually negatively" (Fogg *et al.*, 2003, p. 7).

In the same survey, 8.8% of comments suggested that: "a Web site wins credibility points by giving information about the organization behind the Web site: who they are, what they do, and how to contact them" (Fogg *et al.*, 2003, p. 7).

> In 14.1% of the comments, users referred to issues of reputation and name recognition. Users frequently commented on unfamiliar sites, typically harming the credibility of the site. In other cases, people saw a familiar company name and inferred that the site was credible because of that (Fogg *et al.*, 2003, p. 7).

It should be noted that only in 3.4% of the comments did people claim that a site won credibility by showing an affiliation with an organisation such as a university. However, the nature of the sites included in the survey is such that many of the sites would have no reason for any such affiliation. It's possible that this low score reflects the rarity of the affiliation rather than its lack of importance.

The CAMS website starts from a strong position: it's associated with a number of well-respected (albeit academic) institutions, carries no advertising, and its motive (simply to educate the public) is clear.

2.3 Design implications

Academic reputation alone isn't sufficient to gain a website credibility with the lay public. The advantages mentioned above are significant, but overall Fogg *et al* found the most important factors in a site's credibility with the public to be the "design look", followed by "information design/structure". In a linked study, it was found that members of the lay public were more likely than experts to be influenced by a site's "overall visual design... including layout, typography and colour schemes" (Stanford, Tauber, Fogg, & Marable, October 2002). When designing a site for the public, it's important to keep that audience in mind. "Don't build a site for your executives; they aren't the target audience. Know the characteristics of your target audience and write for them" (Lattimore, Baskin, Heiman, & Toth, 2007, p. 139).

The conclusions to be drawn from these findings are:

- That the site shouldn't rely solely on the reputations of CAMS and the ANU to provide credibility, and make it stand out from the crowd;
- That the design preferences of the expert physicists at CAMS won't necessarily match the requirements of the real audience for whom the site is intended.

2.4 *Overview of method*

2.4.1 Requirements gathering

I began by meeting CAMS' Chief Operations Officer and Research Director, in late 2007, to establish their broad requirements.

2.4.2 Interviews

The next stage was to conduct a series of semi-structured interviews with CAMS' Research Director, in order to identify the themes CAMS wished to communicate. I was able to advise CAMS on their choices of media and topic, within the constraints of CAMS' immediate requirements.

2.4.3 Client approval

I distilled my notes and audio recordings of the interviews into documents to be reviewed and approved by CAMS.

2.4.4 Creation of the communication material

Based on the topics identified in the interviews, I provided consultancy to CAMS in the writing of a public lecture, and created a preliminary survey to evaluate the audience's reactions to the lecture.

I used the content of the lecture, and to some extent the audience feedback from the survey, as the basis for the communication material which constitutes the artefact which this thesis chiefly describes.

This communication material was designed, in accordance with current ideas about best practice in Science Communication, to inform the public about antimatter, its discovery and applications, and the research being conducted at CAMS.

2.5 *Significance of the current project*

There are many contentious scientific issues in the mainstream news at the moment, and compared to (for example) nuclear power, climate change or stem cell research, a better knowledge of antimatter is unlikely to have a direct impact on anyone's life. However, a site such as this can still have a beneficial effect on the public's awareness and understanding of science.

- It can be a source of accurate, unbiased information: there are still very few good web resources about antimatter.
- It can improve scientific literacy. By giving examples of science in action, and the history of the discovery of antimatter, it can demonstrate the scientific method, and show how real science is done.
- By making apparently obscure science more accessible, it can improve the public image of science in general.
- It can stimulate interest in science. If visitors to the site find the content comprehensible and interesting, they might be inspired to learn more about other aspects of science.
- It can show that atomic and nuclear research is not all about bombs, and that research which seemed esoteric in its day can have real-world benefits for the whole of society.

A site of this nature can also set an example to other scientists: here is a world-class research facility, taking seriously its responsibility to communicate its research to the public.

3 Review of related literature, part 1: science communication

3.1 History of science communication

3.1.1 Early science communication

There has been some form of communication about science for as long as science itself has existed. From its foundation in 1799, the Royal Institution was dedicated not only to scientific research, but also to the public communication of science.

Similarly, when the British Association for the Advancement of Science was formed in 1831, one of its aims was "to obtain more general attention for the objects of science and the removal of any disadvantages of a public kind which impede its progress" (Briggs, 2001, p. 191). This statement even predated, by three years, the coining of the very term "scientist" (at a later meeting of the British Association) (Briggs, 2001, p. 192).

Over the intervening years, many like-minded organisations have come into being throughout the world, and a good deal of well-intentioned effort has gone into the communication of science. However, it is really only in the last few decades that Science Communication has been widely recognised as a discipline in its own right.

3.1.2 A recent history of science communication

In 1985 the Royal Society published a report entitled *The Public Understanding of Science* (The Royal Society & Bodmer, 1985). Often referred to as the Bodmer Report, after Walter Bodmer, the chair of the committee which produced it, the report led to the establishment (jointly by the Royal Society, the Royal Institution and the British Association) of COPUS, the Committee on the Public Understanding of Science. The Bodmer Report and COPUS were responsible for significant changes in the way in which science was communicated to the public. The new Public Understanding of Science movement saw scientists themselves encouraged to communicate with the public about their work, and it emphasised that communication was a legitimate part of scientific study.

Eight years later the UK government published a science policy statement entitled *Realising Our Potential*, which included a requirement that the UK's research councils promote public understanding of the sciences (Office of Science and Technology, 1993).

However, within fifteen years of its inception the Public Understanding of Science movement had become discredited: it was widely seen as patronising, and neglectful of the interests and wishes of the public. In 2000 the Science and Technology Committee of the House of Lords published a report entitled *Science and Technology - Third Report* which suggested that the Public Understanding of Science movement was arrogant, and recommended that science communication should become more of a two-way process (House of Lords, 2000).

> The expression 'public understanding of science' may not be the most appropriate label. ... It is argued that the words imply a condescending assumption that any difficulties in the relationship between science and society are due entirely to ignorance and misunderstanding on the part of the public; and that, with enough public-understanding activity, the public can be brought to greater knowledge, whereupon all will be well. This approach is felt by many of our witnesses to be inadequate; the British Council went so far as to call it 'outmoded and potentially disastrous'. (House of Lords, 2000, section 3.9)

Amid calls for greater transparency, openness and dialogue, COPUS itself began to appear outdated and irrelevant to the public's needs. David Dickson reports:

> To quote a statement made by the UK's Committee on the Public Understanding of Science (or COPUS) — itself a manifestation of a belief in the traditional 'deficit model' approach to science communication — when it decided to close shop in December 2002, 'We have reached the conclusion that the top-down approach which COPUS currently exemplifies is no longer appropriate to the wider agenda that the science communication community is now addressing.' (Dickson, 2005)

3.2 Communication, awareness and understanding

In the late Twentieth Century and early Twenty-First Century the emphasis has shifted somewhat, away from Public Understanding of Science, and towards Public Awareness of Science.

> On occasions, the term 'public awareness of science' has been used as a synonym for 'public understanding of science'. Their aims are similar and their

> boundaries do overlap, but PAS is predominantly about attitudes toward science. PAS may be regarded as a prerequisite—in fact, a fundamental component—of PUS and scientific literacy. (Burns, O'Connor, & Stocklmayer, 2003, p. 187)

This change of focus from understanding to awareness should not be misinterpreted as "dumbing-down".

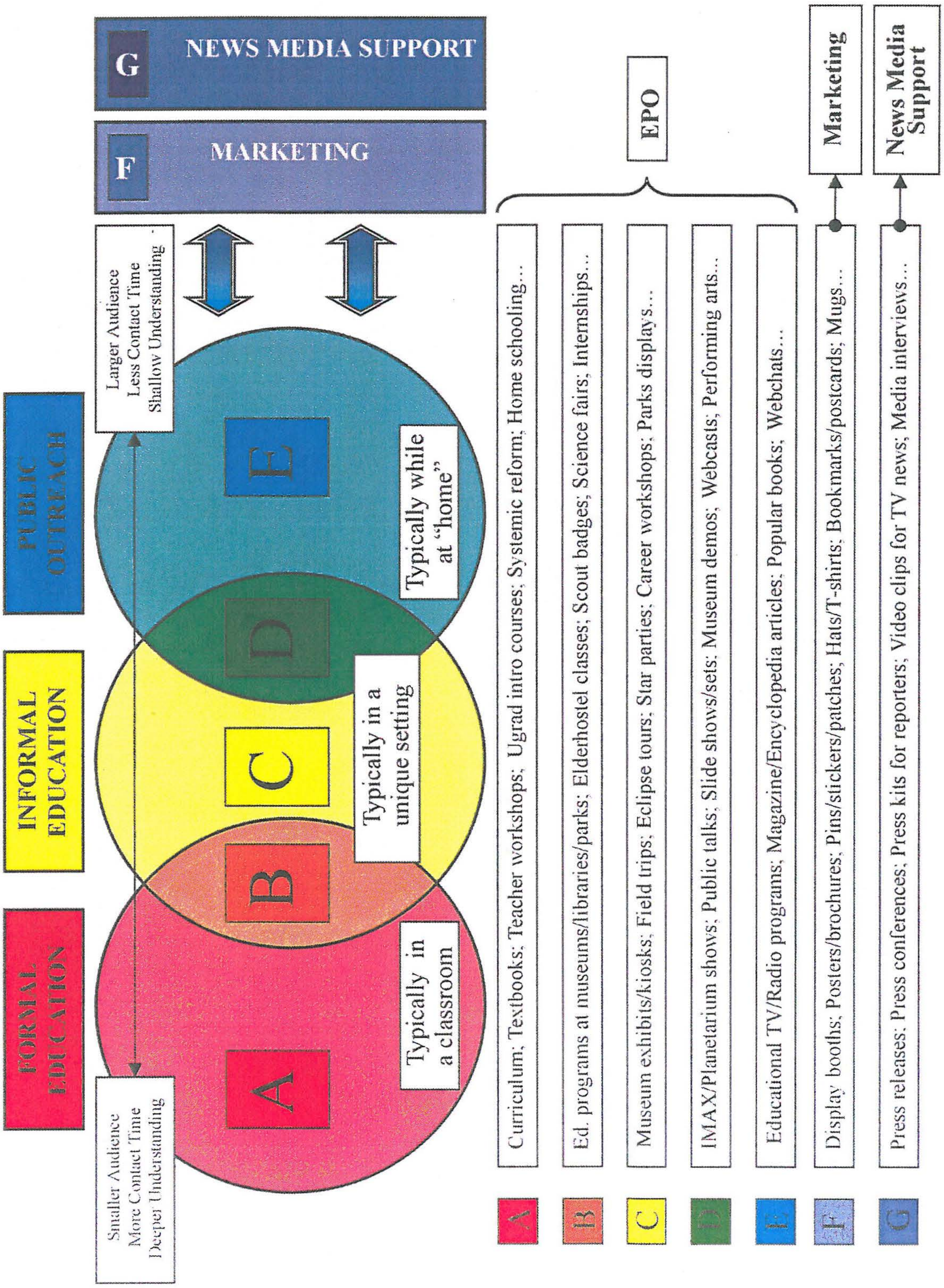
> The significance of awareness should never be underestimated. ... For science, it provides the foundations of knowledge, broadens the mind and opens up personal and public opportunities that did not previously exist. (Burns *et al.*, 2003, p. 196)

After the backlash against the Public Understanding of Science movement, it can now be seen that understanding and awareness both have their role to play. There is no clear boundary between communication designed to promote awareness, and communication to increase understanding: science communication can be viewed as a continuum rather than a set of discrete methods (Burns *et al.*, 2003). The art of good communication is to position the communication material appropriately for the subject matter and audience.

3.2.1 Positioning this project: awareness or understanding?

Morrow illustrates the breadth and interconnectedness of science communication activities with the following diagram:

Figure 1. A conceptual framework to distinguish among the realms known as Formal Science Education, Informal Science Education, Public Outreach, Marketing, and News Media Support (Morrow, 2000)



Morrow doesn't specifically use the word "awareness", but refers to "deeper understanding" at one end of the spectrum and "shallow understanding" at the other. The "shallow understanding" region of the diagram is where public relations and marketing activities, intended to raise awareness rather than increase understanding, are to be found.

She shows how communication material can vary: from detailed information, delivered to an engaged and receptive audience in an academic setting; via museum exhibits and television shows, for an audience which must be entertained as much as informed; and finally to items such as press releases and posters, which must vie to attract an audience at all.

Referring to Sections B, C and D of the diagram above, Morrow says:

> Products and activities in the informal education realm tend to combine the educational substance of formal education with the excitement and relevance of successful public outreach. ... Informal learning opportunities are active and voluntary and are intended to provide motivation for further formal learning and life-long interest. (Morrow, 2000)

This is a good description of the aims of this project.

Visitors to the web site will already have been drawn in, whether by a personal recommendation, by an interesting link from another site, by some other form of publicity, or simply by having searched for material which matches the site's content. For this reason, the site does not have to address the concerns of Sections F and G of the diagram. At the other extreme, the material is not intended to be delivered in a classroom setting, so does not really fall within Section A of the diagram.

The site's content is technical and educational, which is reflected in its fairly didactic structure. This might suggest that the site is close to the formal education end of the continuum. It is certainly true that the aim of the site is to increase understanding, more than to raise awareness. However, the informal nature of Internet writing, combined with the deliberate decision to omit the mathematics, means that in fact the site could be considered to belong to Sections C, D or E.

3.3 *Science and the public*

3.3.1 Public knowledge of science

An analysis of surveys conducted in the USA in 1995 and 2001 found that only about fifty percent of respondents (to each question) knew:

- that the earliest humans did not live at the same time as dinosaurs;
- that it takes the Earth one year to go around the Sun;
- that electrons are smaller than atoms. (American National Science Board & American National Science Foundation, 2002, p. 10 of Chapter 07)

The overwhelming majority of studies of this nature relate to the USA, and not all of their findings can necessarily be extrapolated to the rest of the world. For example in the 2001 survey, <u>for the first time</u>, a majority (albeit just fifty-three percent) of respondents agreed with the statement "human beings, as we know them today, developed from earlier species of animals". The authors of the official report on the surveys note without comment that this brings the United States "more in line" with other industrialised countries (American National Science Board & American National Science Foundation, 2002, p. 12 of Chapter 07).

The topics may vary, but ignorance of science is not a uniquely American problem (Durant, Evans, & Thomas, 1989) (Durant & Evans, 1989) (Durant, Evans, & Thomas, 1992). Although up-to date information relating to other countries is scarcer, where it exists it suggests that ignorance of science facts (as is the case with ignorance of other aspects of human culture) is generally as widespread (Gup, 2000).

There is almost universal agreement that significant gaps exist in public knowledge of science, throughout the industrialised world. As will be discussed below, there is less agreement about the significance of this finding.

3.3.2 Scientific literacy is not the same as knowledge

The more recent of the two American surveys mentioned above (American National Science Board & American National Science Foundation, 2002) also found that about seventy percent of respondents did not understand the scientific process. Although slightly more than fifty percent had some understanding of probability, and more than forty percent were familiar with how an experiment is conducted, only thirty-three percent could provide a good explanation of what it means to study something scientifically. The report states: "Understanding how ideas are investigated and analyzed is a sure sign of scientific literacy. Such critical thinking skills can also prove advantageous in making well-informed choices at the ballot box and in other daily living activities." (American National Science Board & American National Science Foundation, 2002, p. 2 of Chapter 07)

This question of scientific literacy is a separate issue from knowledge of scientific facts. It can be argued that an understanding of the principles of science, and how science works, is more important than being able to state, for example, that antibiotics do not kill viruses.

In Thomas and Durant's view, scientific literacy requires:

- a basic knowledge of science and technology;
- the skills to interpret new developments in science and technology;
- and the correct attitudes to respond actively and effectively to these developments where appropriate. (Thomas & Durant, 1987)

Scientific literacy, they go on, "may be regarded as a basic survival skill in a scientifically and technologically sophisticated society" (Thomas & Durant, 1987, p. 11). It enables people to live with and benefit from scientific and technical expertise, rather than being oppressed by it.

However, scientific literacy is not merely a survival tool: a knowledge of science can be personally and culturally enriching. Thomas and Durant claim that "individuals differ in the extent to which they gain intellectual and aesthetic satisfaction from great art or great literature; and presumably the same is also true of great science" (Thomas & Durant, 1987, p. 12). Nevertheless, an important goal of the promotion of scientific literacy, they suggest, is to ensure that science is as available and accessible to the public as are other products of human creativity. Rather this than "the prospect of creating a society composed entirely of professional scientists-cum-science policy analysts!" (Thomas & Durant, 1987, p. 13).

Hazen and Trefil have a simpler definition. They see scientific literacy as:

- the general knowledge to understand science items in the news;
- the ability to put these science items into context, as with any other news items. (Hazen & Trefil, 1991)

In the introduction to their book *Science Matters: Achieving Scientific Literacy*, they report that only seven percent of adult Americans met these criteria, at the time of publication. It should be noted however that this might be a case of special pleading, given that buying and reading the book would, according to the authors, improve the reader's scientific literacy (Hazen & Trefil, 1991).

Despite the broad spectrum of opinions about exactly what constitutes scientific literacy, a few general principles emerge. Scientific literacy (as contrasted with scientific knowledge) doesn't require expertise in any particular field of science, but has more to do with the ability to deal with scientific issues in general. It entails an understanding of the scientific method, and an awareness of its strengths and weaknesses. It enables the individual to make informed choices about the effects of science on personal and public life.

3.3.3 Science communication with the public

Thomas and Durant begin their paper *Why Should We Promote the Public Understanding of Science?* by stating, "The public understanding of science is widely regarded as A Good Thing. Given that it is difficult to argue against the greater comprehension of almost anything by almost anybody, this is not particularly surprising" (Thomas & Durant, 1987, p. 1).

However, science is not "almost anything". Communicating science with the public presents its own unique challenges, as Carl Sagan points out:

> Imagine you seriously want to understand what quantum mechanics is about. There is a mathematical underpinning that you must first acquire, mastery of each mathematical subdiscipline leading you to the threshold of the next. In turn you must learn arithmetic, Euclidean geometry, high school algebra, differential and integral calculus, ordinary and partial differential equations, vector calculus, certain special functions of mathematical physics, matrix algebra, and group theory. For most physics students, this might occupy them from, say, third grade to early graduate school – roughly fifteen years. Such a course of study

> does not actually involve learning any quantum mechanics, but merely establishing the mathematical framework required to approach it deeply.
>
> The job of the populariser of science, trying to get across some idea of quantum mechanics to a general audience that has not undergone these initiation rites, is daunting. (Sagan, 1995, p. 249)

There is also a widespread perception in the media that science is too difficult for the general public, and of no interest to non-scientists. Professor Frank Close, of the Department of Theoretical Physics at the University of Oxford has noted that:

> In October 1897, The Philosophical Magazine ... published a paper by J. J. Thomson in which he describes his discovery [of] the particles we now know as electrons... We had tried to get the British post office to issue a stamp to celebrate this seminal centenary. However, instead they chose to celebrate the centenary of the children's author, Enid Blyton. This is what science has to compete with! (Close, 2002, p. 6)

Even if media resistance can be overcome, scientists cannot assume that the public will immediately be receptive to all and any communication about science. "As far as the community is concerned, science is invisible until such a time as it has a need for it. It is a task of the science communicator to demonstrate to the community that it has such a need" (Stocklmayer, Gore, & Bryant, 2001, p. x).

This is not to suggest that science communication consists of simply persuading the media to spread the word about the good work of scientists, as a means of raising the consciousness of an ignorant public. Science communication, as summed up by Eckersley:

> ...is, and must be, about much more than "selling" science to the public. Fundamentally, it concerns the relationship between science and society, and it has a powerful role in shaping this relationship and also in what science is done and how it is used, not just economically, but culturally too. (Eckersley, 2001, p. 83)

Science, then, is not automatically comprehensible to the public; is not automatically of interest to the public; will not automatically appear in media aimed at the public; but has a significant enough influence on modern life that its communication with the public is vital.

3.3.4 Why communicate science with the public?

Despite such difficulties, there is a long tradition of science communication with the public, for reasons both practical and cultural.

> Julian Huxley, in the process of carving out a niche for himself as a popular science writer in the 1920s, offered a simple credo: that it is part of a scientist's duty 'to make available to the lay public the facts and theories of their science, and especially to try and re-create something of the mental background that is engendered by those facts and theories'. (Turney, 1999, p. 122)

Cribb and Hartomo show how the practical and cultural are intertwined:

> The sixteenth century philosopher Francis Bacon said of science: *nam et ipse scientia potestas est* (knowledge is power). However, over the next 250 years or more this did not preclude those without power from acquiring knowledge and empowering themselves. The rise of general and university education greatly accelerated this trend, but even those without an education could obtain better knowledge and technology with comparative freedom. (Cribb & Hartomo, 2002, p. 1)

Hazen and Trefil warn that if members of the public do not take part in the debate about the effects of science on modern life, decisions will be taken out of their hands either by demagogues or by a scientifically-literate but unrepresentative elite (Hazen & Trefil, 1991).

3.3.5 Arguments in favour of communicating science with the public

Many researchers have enumerated lists of reasons, or of categories of reasons, for communicating science with the public (Stocklmayer *et al.*, 2001) (Maienschein & Students, 1999).

One of the most comprehensive lists is to be found in *Why Should We Promote the Public Understanding of Science?* (Thomas & Durant, 1987, pp. 3-9), where Thomas and Durant identify "Nine Arguments for Promoting the Public Understanding of Science". These are:

1. Benefits to Science
2. Benefits to National Economies
3. Benefits to National Power and Influence
4. Benefits to Individuals

5. Benefits to Democratic Government
6. Benefits to Society as a Whole
7. Intellectual Benefits
8. Aesthetic Benefits
9. Moral Benefits

A few of these categories might appear a little out of date in the Twenty-First Century. In my opinion, "Benefits to National Economies" and "Benefits to National Power and Influence" reflect more on the USA's political view of its place in the Cold-War world of the mid-to-late Twentieth Century, than on science per se. Thomas and Durant quote Philippe Le Corbeiller, Professor of Applied Physics and General Education at Harvard, to the effect that one of the reasons the USA needed more scientists and engineers was "to help spread American influence to the rest of the world" (Thomas & Durant, 1987, p. 4).

> 'Our adversary', [Le Corbeiller] wrote, 'has taken full advantage of the progress of science, not only on the interior front but also in his external propaganda, where he presents himself to the world as the champion of science, the bourgeois countries as sunk in obscurantism.' (Le Corbeiller, 1959) in (Thomas & Durant, 1987, p. 4)

Even Thomas and Durant themselves seem unconvinced about "Moral Benefits", pointing out that:

> Our generation has become accustomed to the idea that a substantial fraction of scientific research and development is devoted to sustaining the international arms race; and in this situation, Bronowski's sweeping claim that 'every machine has been a liberator' [(Bronowski, 1977, p. 2)] has come to seem not so much complacent as utterly fantastic. (Thomas & Durant, 1987, p. 9)

However, the majority of the categories identified by Thomas and Durant are of more lasting significance. The categories of particular relevance to this project are:

- Benefits to Science
- Benefits to Individuals
- Benefits to Democratic Government
- Benefits to Society as a Whole
- Intellectual and Aesthetic Benefits

3.3.5.1 Benefits to science

Under "Benefits to Science" Thomas and Durant refer to, and quote from, an unnamed article by Isaac Asimov, which appeared in *Nature* in 1984:

> 'Without an informed public, scientists will not only be no longer supported financially, they will be actively persecuted'. The difference between understanding and non-understanding, Asimov suggests, is 'the difference between respect and admiration on the one side, and hate and fear on the other' (Thomas & Durant, 1987, p. 3)

In the early 1980s American biologists perceived the need to communicate directly with the public in order to counter the rise of religiously-motivated opposition to the theory of evolution (Thomas & Durant, 1987).

It can also be helpful to communicate with the public a sense of what science *cannot* achieve. If the public acquires unrealistic and unrealisable expectations of science, there is a risk that the public will lose confidence in science, and eventually withdraw its support (Thomas & Durant, 1987).

3.3.5.2 Benefits to individuals

The article quotes from a Royal Society report published in 1985. This report is often referred to as the Bodmer report (see "A recent history of science communication", page 14), but its official title is *The Public Understanding of Science*.

> Ignorance of elementary science cuts off the individual from understanding many of the tools and services used every day. Some basic understanding of how they function should make the world a more interesting and less threatening place. It is obviously not necessary, and hardly possible, for an

> individual to understand the functioning of everything from a bus to a ball point pen or a television set, but those who have never been stimulated to enquire about how things work and who lack the basic knowledge to pursue such an enquiry are surely at a disadvantage in the modern world. (The Royal Society & Bodmer, 1985, p. 10), in (Thomas & Durant, 1987, p. 5)

3.3.5.3 Benefits to democratic government

Increased public understanding of science can lead to better democracy, by encouraging people to exercise their democratic rights where science is concerned, and enabling them to make better-informed choices when they do so. Better public understanding of science does not necessarily bring about consensus, but it can lead to more informed, and therefore better, decision-making (The Royal Society & Bodmer, 1985).

Increased understanding of science does not automatically lead to greater public enthusiasm for science (Dickson, 2005), but it's difficult to argue with the idea that democracy relies on a well-informed electorate.

3.3.5.4 Benefits to society as a whole

In common with a number of other highly-specialised fields, modern science is in danger of becoming separated from everyday life. The American anthropologist Margaret Mead suggested that a "schismogenic process" was alienating lay people from the worlds of science and technology. She believed that this schism could and should be halted by the discovery of "new educational and communication devices" to bridge the gulf between "the specialized practitioners of a scientific or humane discipline and those who are laymen in each particular field." (Mead, 1959), in (Thomas & Durant, 1987, p. 6)

If members of the public do not understand science, they may respond with "a mixture of fear and adulation", which Thomas and Durant feel is intrinsically bad for society as a whole. (Thomas & Durant, 1987, p. 6)

3.3.5.5 Intellectual and aesthetic benefits

Quoting the physicist and novelist C. P. Snow, Thomas and Durant report that:

> For Snow, the scientific edifice of the physical world was 'in its intellectual depth, complexity and articulation the most wonderful collective work of the mind of man' (Snow, 1959) in (Thomas & Durant, 1987, p. 7)

3.3.5.6 Summary of arguments in favour of communicating science with the public

There is a great deal of overlap in the categories outlined above.

At a societal level, it's culturally and politically divisive to have one branch of knowledge controlled by a minority.

At the level of the individual, science is a part of human culture. To be an educated person in the modern world requires an understanding, or at the very least an awareness, of science.

3.4 *Models of science communication*

3.4.1 Ziman's three models

Given that public knowledge of science, and public scientific literacy, appear to be lacking throughout the industrialised world, John Ziman proposed three ways of modelling the problem:

- the Deficiency Model;
- the Rational Choice Model;
- the Context Model. (Ziman, 1992)

According to Ziman, the Deficiency Model represents the "traditional" view that members of the public are "deficient" in their knowledge about science, and that this deficiency can best be rectified through better communication about science. The role of science communication in this model is to help non-scientists become better-informed about what scientists know.

The Rational Choice Model asks, "What do people need to know in order to be good citizens—even to survive—in a culture largely shaped by science?" (Ziman, 1992, p. 16)

The Context Model asks, "What do people want to know in their particular circumstances?" (Ziman, 1992, pp. 17-18)

3.4.2 From deficit to context

David Dickson quotes John Durant, assistant director of the Science Museum in London, and Professor of the Public Understanding Of Science at Imperial College London, as referring to an "outdated and elitist" conveyor-belt principle of science communication, in which "...scientists are seen as placing the 'facts' on one end of the conveyor belt, in the expectation that they will be delivered intact to an expectant and appropriately appreciative public at the other" (Dickson, 1999, p. 197). In fact, many practitioners of what came to be known (somewhat disparagingly) as the Deficit Model of science communication had believed that simply educating the public about science would translate directly into increased public support for science. According to Dickson this hasn't been the case.

> The hypothesis on which the [Deficit] model is based is highly flawed. Increased knowledge about modern science does not necessarily lead to greater enthusiasm for science-based technologies. Indeed, there is considerable evidence to the contrary. For example, the more knowledge an individual has about a potentially dangerous technology (such as nuclear power or genetic engineering), the more concern he or she may well feel about that technology. (Dickson, 2005)

Brian Wynne is credited with coining the term "Deficit Model", in criticism of what he saw as a discredited approach, which underestimated the sophistication of the audience, and overestimated the consistency and self-reflexivity of the scientific establishment. Wynne believes that the Deficit Model itself might be responsible for turning the public against science. "People tend to be alienated from this tacitly patronising, controlling and denigrating imposition of normative models upon them by science, even if they do not show this in open resistance" (Wynne, 1993, p. 334).

Lewenstein agrees that the Deficit Model is weakened by its close links to the power relationship between the "scientifically literate" (defined in each case as those who possess the particular knowledge measured by a specific survey) and the "scientifically illiterate" (those who do not). (Bruce V. Lewenstein, 2003)

Lewenstein also identifies a problem with the very idea of a deficit, as contained in the Deficit Model. When attempting to measure public knowledge or understanding of science by means of asking factual questions, many surveys have asked these questions without providing a context.

> Learning theory has shown that people learn best when facts and theories have meaning in their personal lives; for example, research has shown that in communities with water quality problems, even people with limited education can quickly come to understand highly complex technical information. But in

> what situation with personal relevance, for example, does a nonscientist need to know the definition of DNA? (Bruce V. Lewenstein, 2003, p. 2)

In a survey by Durant, Evans and Thomas, British adults were asked what it meant to study something scientifically. Although few respondents gave a "satisfactory" answer (one which referred to either the experimental method, or to theory construction), the authors note that that his may have more to do with unfamiliarity with the technical vocabulary than any lack of comprehension of science. "Although fewer than fourteen percent of respondents mentioned experimentation unprompted, more than fifty-six percent opted for the experimental approach when given a choice between alternative methods of investigating a problem." (Durant *et al.*, 1989, p. 12)

Ziman also points out that science is not "a well-bounded, coherent entity, capable of being more or less 'understood' " (Ziman, 1992, p. 15). Scientists often disagree about what constitutes science, and about how to interpret its findings. It follows that adopting a model such as the Deficit Model, which assumes a single body of knowledge, able to be communicated directly and simply to a receptive audience, is likely to lead to difficulties.

The Deficit or Deficiency Models can be seen as too closely tied to the world-view of the scientific establishment, whereas other models take the audience's requirements more into account.

The Rational Choice Model is something of a halfway house between the Deficit and Context Models. Where the Deficit Model simply ascertains the nature of a putative deficit in public knowledge, and then seeks to fill it, the Rational Choice Model begins by considering the audience's needs. However, it may still suffer from the assumption that there is a prescribed set of information which the public "ought" to know, and that this set can be determined by the scientific establishment.

The Context Model, which begins by considering the interests and needs of its audience, is therefore currently the preferred model of many science communication researchers (Ziman, 1992) (B. V. Lewenstein, 1992). In the Context Model, the onus is on scientists to raise public awareness of their work by making it accessible and relevant, rather than expecting the public to learn how to interpret it (Gregory & Miller, 1998).

Models of science communication are still evolving, and any model representing a complex process can only be an approximation. A model can be a useful tool, but it's important not to confuse the model with reality, and to remember that different models may also be relevant.

3.4.3 In defence of the Deficit Model

No single model perfectly represents the communication process. In practice, almost any communication can be seen as combining elements of several models. Dickson states that, in context, an improved version of the Deficit Model can sometimes be the most efficient way of communicating the plain facts. "I believe that the 'deficit model' approach, for all its weaknesses, can still play an important role in facilitating effective participatory and democratic decision-making" (Dickson, 2006, p. 1).

Dickson isn't referring to the classic Deficit Model (since the phrase was coined as a criticism of a flawed technique) but rather to the practice of delivering straightforward factual information, which he believes is essential before meaningful dialogue can occur. "Substantial and effective dialogue will only take place when those on both sides have a sound understanding of the relevant factual evidence" (Dickson, 2005). Dickson warns of the danger that, "without a solid grounding in robust, reliable knowledge ... dialogue may end up producing more heat than enlightenment." (Dickson, 2006, p. 3)

Lewenstein believes that:

> As Steve Miller has suggested (personal communication, 1 May 2003), the value of the deficit model can be rehabilitated by a shift from the 'moral pressure / you have to know this' approach to a 'softer / you might want to know this' approach (as in, 'You might want to consult the WHO website on SARS before traveling to China'). (Bruce V. Lewenstein, 2003, p. 6)

The Internet can be a powerful source of information, and has democratised access to factual knowledge. Scientific information is no longer the sole preserve of a formally-educated social elite, and so the power relationship between scientists and the public has altered, weakening one of the historical objections to the Deficit Model.

As long as good, informative websites exist, individuals can have direct access to scientific knowledge, and will be better able to take part in the debate about science.

> The information that we can glean from the Internet means that we are far better placed to know the type of questions that we need to put to technical experts, to spot the weaknesses and holes in their answers, and to make up our own minds on important issues. (Dickson, 2006, p. 3)

There's a place for Deficit-Model style communication, used sparingly and in the correct context. It can be an appropriate method of delivering "the facts", and a good first step towards enabling informed two-way communication.

3.4.4 Constructivism

The theory of Constructivism is based on the work of Piaget, Vygotsky, Dewey, Bruner and Neisser. (Huitt & Hummel, 2003) (Heylighen, 1995a)

Constructivism is a model of the way in which people learn, so it has important implications on the design of factual or educational communication material. Constructivism states (among other tenets) that we don't learn by absorbing new information in a vacuum: we project what we already know or believe onto every new phenomenon we observe. People learn by constructing new concepts based on their prior knowledge and experience.

> Constructivism suggests that knowledge is constructed, not transmitted. Constructivism, therefore, is concerned with the cognitive process that proceeds the actual communication within a given situation rather than with the communication itself.
>
> This theory suggests that in communicating, it is important to have some knowledge of the receiver and his or her beliefs, predilections, and background. Simply dispensing information and expecting receivers to believe in or act on it, according to this theory, is a fool's errand. The task of the communicator, rather, is to understand and identify how receivers think about the issues in question and then work to challenge these preconceived notions and, hopefully, convert audience members into altering their views. (Seitel, 2007, p. 49)

If learners have existing ideas which conflict with those of the teacher, they can be reluctant to abandon their prior knowledge. This prior knowledge might be the "naive" ideas of a student entering his or her first science class (Resnick, 1983); it might have been built up over a lifetime of empirical experience; or it might have been handed down through centuries of cultural tradition. In any case, learners will often try to assimilate any new idea into what they already believe. This can lead to problems if the idea really doesn't "fit" the student's preconceptions. "Even after instruction in new concepts and scientifically supported theories, [students] still resort to their prior theories to solve any problems that vary from their textbook examples" (Resnick, 1983, p. 477).

Francis Heylighen refers to "individual constructivism", which:

> ...assumes that an individual attempts to reach coherence among ... different pieces of knowledge. Constructions that are inconsistent with the bulk of other knowledge that the individual has will tend to be rejected. Constructions that succeed in integrating previously incoherent pieces of knowledge will be maintained. (Heylighen, 1995b)

It is therefore important to address learners' existing ideas, and take their alternative conceptions about the world into account when creating any informative communication material, whether scientific or otherwise.

Popular culture is loaded with references to science, pseudo-science and science fiction. Antimatter, or at least a fictionalised concept of antimatter, features in (among other works) *Star Trek*, *Dr Who*, and *Angels and Demons* (a novel by Dan Brown, author of *The Da Vinci Code*). Many visitors to the CAMS website will have existing ideas (which may be erroneous or accurate) about the subject matter, based on popular culture and on their own prior knowledge of science. The website includes references to antimatter in science fiction, and a *Fact or Fiction* section (Antimatter: does it matter?, 2009b) to address some of the more prevalent "naive" or alternative conceptions about antimatter.

Many visitors will also have heard the expression "PET scan". They may even have had a PET scan, or know someone who has. The communication material will "humanise" the physics of a PET scan by presenting the process from the patient's point of view.

3.5 Summary of literature review part 1: science communication

There is clearly a place for factual science information on the Internet, for cultural and practical reasons.

Science can and should enrich people's lives throughout society, in the same way as any other cultural activity.

Scientific literacy is necessary in modern society, but not sufficient in itself. Dickson believes that a sound factual knowledge is essential in order to achieve scientific literacy. To return to the words of Francis Bacon, "Knowledge is power", and an authoritative, informative website is an effective means of empowering a large section of the public.

This project will largely provide specific scientific information, as the client requested. It will also address the questions of misconceptions and scientific literacy, through the *Fact or Fiction* section (Antimatter: does it matter?, 2009b), and the use of the story of the discovery of antimatter to illustrate the scientific method (Antimatter: does it matter?, 2009a).

In accordance with Constructivist principles of learning, I recommend that the online survey (Antimatter: does it matter?, 2009c) be developed and monitored closely, in order to learn more about the site's visitors' prior knowledge and beliefs about antimatter.

4 Review of related literature, part 2: writing, and web writing

4.1 *Communication is an art, not a science*

There's no shortage of advice about written communication; no shortage even, in the Twenty-First Century, of advice on writing about science. Sadly, much of it is so vague that it boils down to advice to try to write well, and not to write badly.

Turney sees the problem as twofold. First, there is the technical matter of writing good explanations:

> If there is one thing you have to do as a science writer, it is to explain unfamiliar ideas and phenomena. But it is hard to find any systematic account of how this is done. Advice to authors usually boils down to avoiding equations, minimising jargon, striving for clarity, and using apt metaphors and analogies. It is certainly worth bearing all these in mind. Yet even when you do, it is still hard to define when the job has been done well for the intended audience. (Turney, 2001, p. 49)

Then there is the question of how to convey complex concepts:

> What kinds of things are the scientifically defined entities – atoms or genes – which no-one ever normally sees? What does it mean to conceive of gravity as a distortion of space-time around a massive object? What are virtual particles, electron tunnelling, evolutionarily stable states or hydrogen bonds? And if we want to learn about any of these things, how do we recognise an effective explanation when we see one? (Turney, 2001, p. 55)

Turney believes that "Many popular writers, one suspects, build their explanations by trial and error – seeing what looks right, or sounds intelligible as they work on their text, noting readers' difficulties, and checking out others' explanations of their subjects" (Turney, 2001, p. 55).

An empirical approach is certainly better than never checking at all to see if your communication has succeeded. There are some well-established guidelines which can help to circumvent some of the trial and error (as detailed below) but it's still important to evaluate the effects of any communication material, to make sure it has reached its audience.

4.2 *Know the audience*

According to Stocklmayer, "The simple answer is to know the audience and to tailor the communication expressly for them. This is of course not simple at all. It is almost impossible" (Stocklmayer, 2001, p. 18).

The CAMS website is aimed at the broadest possible audience, and in its initial incarnation will have to be produced almost "blind". In the real world it isn't always feasible to start with the huge quantities of audience research which are required in order to know the audience fully. It's more practical to make some material available to the public, then refine and revise that material, than simply to provide no information whatsoever until the end of a lengthy process of audience evaluation.

It is at least possible, from the outset, to try to put yourself in the position of your audience, and ask yourself the questions they might reasonably ask. For instance, as a starting point:

> 'What have you got for me? Why is this important? What are you suggesting? Why that? How did you arrive at that conclusion? What do you have to back that up? What do we do now? What are the implications? What is the down side?' These realistic work-focused questions will help you to write documents that meet your readers' needs. (Mohan, McGregor, Saunders, & Archee, 1997, p. 291)

4.3 *Needing to know, and wanting to know*

Knowing your audience also involves an understanding of what your readers want to learn. At the same time, when communicating a complicated topic, there is also the practical matter of providing the facts they need in order to make sense of the material.

> It is the prospect of studying *modern* physics (special and general relativity, elementary particles, quantum theory, and astrophysics) that has the most influence in persuading students to study physics at university level. Yet little is done systematically to introduce young people to these 'shop window' topics at school. It is largely left to chance whether children casually pick them up through the press or television. Not that one wishes to denigrate the importance of laying a good school grounding in traditional classical physics. What is advocated is a balance – one struck between what physics teachers know students *ought* to learn and what the students themselves *want* to learn. Rather

> than taking students' interest for granted, we must capture and stimulate it by consciously and deliberately seeking ways of making physics more attractive. (Stannard, 1999, p. 135)

Finding this balance, between providing the facts and interesting the audience, is crucial: while the material cannot be understood without the basic facts, the facts are of no value if the audience is not sufficiently engaged to learn them. Many authorities agree on the importance of finding a good "hook", an introduction that will encourage readers to continue with the article.

> Remember you are writing for volunteer readers, listeners and viewers. (Newsom & Haynes, 2008, p. 131)

> Find an introduction to seduce a half-interested reader. (Lublinski, p. 11)

> Novels or short stories may generally save the best for last, but a science communication article needs to start with a bang — an attention-grabbing fact, question or the like. (Leite Vieira, 2008)

> A complex, science-heavy first paragraph or introduction, with formulas and difficult concepts, is an infallible recipe for making the reader abandon an article after the first few lines. (Leite Vieira, 2008)

> Intrigue people with the first few words so they'll want to read more. (Newsom & Haynes, 2008, p. 299)

> Provide a hook to hang your story on. ... Start with your main finding or point and tell the whole story in the first sentence or two. Use the rest of your space or time to add colour and more detail. Sum up at the end, repeating your main point. (Anderson, 2006, p. 6)

The introductory hook can often be achieved by placing the science in the context of the reader's own life.

> Ask the researcher during your interview why creating nanotubes from DNA molecules could be revolutionary for computer technologies. Or explain to your readers how stem cell research has the potential to discover cures for disease. Try the narrative technique of introducing your story by writing about someone afflicted with a disease and explain how stem cell research could change this condition. (El-Awady, p. 13)

Stocklmayer believes this is essential. "If you don't place the communication in the world of the audience, they will not listen or read further" (Stocklmayer, 2001).

4.4 No maths, no graphs, no formulas

In the introduction to his popular science work *A Brief History of Time*, Stephen Hawking tells of being advised that each equation he included would halve the book's sales (Hawking, 1988, p. vi). Even simple mathematics can be intimidating to non-scientists, and communication which intimidates its audience will fail, because the audience will simply move on, without paying attention. Stocklmayer advises that, in order to stand the best chance of being read at all, science communication aimed at the public should omit as much of the mathematics and as many formulas as possible. "It's a terrible barrier, in the truly old-fashioned sense of striking terror into many of your audience" (Stocklmayer, 2001, p. 18).

Resnick, although referring specifically to teaching children, makes a parallel point. She found that mathematics, introduced too soon, could actually be a hindrance to understanding. "Teaching has to focus on the qualitative aspects of scientific and mathematical problem situations. Too quick an advance to formulas and procedures will not help children acquire the kinds of analytical and representational skills they need" (Resnick, 1983, p. 478).

The mere presence of numbers on a web page can be problematic, although Nielsen found that "numerals often stop the wandering eye and attract fixations, even when they're embedded within a mass of words that users otherwise ignore" (Nielsen, 2005).

Where numbers are essential in online text, Nielsen has following advice:

- Write numbers with digits, not letters (23, not twenty-three).
- Use numerals even when the number is the first word in a sentence or bullet point.
- Use numerals for big numbers up to one billon:
- 2,000,000 is better than two million.
    - Two trillion is better than 2,000,000,000,000 because most people can't interpret that many zeros.
    - As a compromise, you can often use numerals for the significant digits and write out the magnitude as a word. For example, write 24 billion (not twenty-four billion or 24,000,000,000).
- Spell out numbers that don't represent specific facts. (Nielsen, 2005)

El-Awady recommends helping the audience to visualise a number, by making comparisons with things that we see or use in our everyday lives. Even then, she stresses:

> Take care to limit the number of numbers in an article to just the most important ones – so as not to alienate your readers. ... Don't be afraid to use the word "approximately" and simple rounded-up or rounded-down whole numbers rather than fractions. (El-Awady, p. 16)

A review of literature by the Nanoscale Informal Science Education Network found that science communicators should avoid graphs, and especially multidimensional graphs and log scales (Crone, 2006, p. 8). Leite Vieira has the same advice about formulas and chemical equations. If it is absolutely necessary to include a formula, he says, "Even known formulas such as $E= mc^2$ should be explained" (Leite Vieira, 2008).

Illustrations can still be useful: the Web is a visual medium. Yates says that web writers should always be asking themselves "Do I need to write these words?" and considering whether an illustration would make the point more succinctly (Yates, 2007). On the other hand, Mohan *et al* make the practical point that graphics are only of use if they are kept simple. "If you have to puzzle over a graphic then you might as well be reading the same message in a table or a paragraph of text" (Mohan *et al.*, 1997, p. 343).

4.5 Start with a plan

Any written communication beyond a paragraph or two should start with a plan. According to the World Federation of Science Journalists, "A well-written story does not just add many loosely connected facts but follows a certain 'red thread'. It should be obvious to the reader why one paragraph follows the next" (Lublinski, p. 11).

What is left out can be as important as the content of the article. "A good science reporter avoids drowning the reader in information. ... you need to decide which aspects to define in simple language, or explain in detail" (Lublinski, p. 11).

> Don't try to tell readers everything you know. That always takes you to fringe areas, where your knowledge gets a little shaky and errors begin to creep in. Statements perfectly consistent with what you know might be inconsistent with

what you don't know. Besides, if you tell the readers everything you know, you're probably telling them a lot more than they want or need to know. Give readers just what they need to get the message. (Newsom & Haynes, 2008, pp. 119-120)

4.6 Structure

Structure is vital to any written communication (Lattimore *et al.*, 2007); all the more so in an interactive context such as a web page, where users can enter at any point, and follow links in any order they choose. The nature of the World Wide Web is such that a search engine will frequently introduce readers to the site at some random point in the middle of a random section of a website. A simple, consistent structure, which is easy to navigate, can help these readers to orient themselves, and begin to make sense of the material. (Yates, 2007)

> Build in a clear orientation so students can understand where they are and that the various pieces of information are connected. Navigation maps and consistent interface design help with this. (Garrand, 2001, p. 69)
>
> A well-designed information architecture not only helps users find the information they want, but it is also one of the most effective ways to initiate interaction... Good information architects know how to hook the user by placing the most appropriate content on the top level of the interactive program, such as a Web site's home page where most users first arrive. After hooking the user, this top level information has to lead the user logically to the information that the user wants or that the designers want them to see. ... Structuring your site so that there are several ways to access information is also important. (Garrand, 2001, p. 27)

A sequence of ideas can be a powerful tool, as each new concept can help to explain the next. In his later work *Opus 100*, Isaac Asimov describes the experience of writing his book *Realm of Numbers* (Asimov, 1959) :

> It was about elementary arithmetic... it was not until the second chapter that I as much as got to Arabic numerals, and not until the fourth chapter that I got to fractions. However, by the end of the book I was talking about imaginary numbers, hyperimaginary numbers, and transfinite numbers - and that was the real purpose of the book. In going from counting to transfinites, I followed such a careful and gradual plan that it never stopped seeming easy. (Asimov, 1969, p. 87)

4.7 *The modular nature of web writing brings its own difficulties*

Web designers need to be aware that users may not choose to follow a prescribed sequence when visiting a website. Each page or section of a site needs to be comprehensible in its own right (Yates, 2007), also (Holtz, Undated) in (Newsom & Haynes, 2008, p. 287).

However, this doesn't prevent the information architect from <u>suggesting</u> an order in which the material is best viewed.

> Modular course structures, especially those with open entry systems, present instructors with particular problems in respect of subjects like science that have a strongly sequential or hierarchical knowledge base. An understanding of many concepts in science requires a grasp of a significant number of lower-level concepts. Thus, before physics students can analyse a collision, they need to have understood the concepts of mass, velocity and speed, momentum, energy, and conserved quantities, and each of these concepts can be unpacked in their turn to produce an even lower-level list. The syllabus for any science course is in fact an elaborate edifice based on assumed prior knowledge. (Ross & Scanlon, 1999, p. 48)

For this reason, although the design of the CAMS communication material is modular, it also has links which can guide the reader through each module in a logical fashion, if the reader chooses to make use of them.

4.8 *Keep grammar and syntax simple*

4.8.1 Active or passive voice

The days when all writing about science had to use the passive voice are long gone. Almost all advice now recommends the active voice (Garrand, 2001, p. 18) (Mohan *et al.*, 1997, p. 289) (Lattimore *et al.*, 2007, p. 140) (Anderson, 2006, p. 6), although Peter Wrobel (managing editor of the journal "Nature") still believes that the message has not fully sunk in. "Passive sentences are notoriously common in science writing ... They slow sentences down, and put a brake on readability" (Wrobel, 2008).

For all that the active voice is the preferred default, the passive voice still has its place, if used sparingly. The passive voice can make the meaning clearer if the agency is unknown (Penman, 1993, p. 124), or if the aim is to emphasise the receiver of the action or the result of the action (Lattimore *et al.*, 2007, p. 138), (Mohan *et al.*, 1997, p. 290).

The passive voice can also help to improve coherence between sentences.

> The illustration [Wilbers] uses is: "We must decide whether to increase our prices. The possibility that we will lose some of our customers should influence our decision." Using the passive voice connects the sentences better: "We must decide whether to increase our prices. Our decision should be influenced by the possibility that we will lose some of our customers. (Wilbers, 1998, p. 13), in (Newsom & Haynes, 2008, p. 134)

4.8.2 Shorter, plainer words, and fewer of them

Shorter, everyday words are easier to understand, for example "helpful" rather than "advantageous". Anderson advises against turning verbs into nouns ('She was engaged in the construction and installation of instruments,' is less clear than 'She built and installed instruments'); and against stringing nouns together ('The public is making more electrical home-improvement supermarket purchases') (Anderson, 2006, p. 6).

Short sentences are clearer than long ones. The consensus is that the average sentence should not be longer than twenty words (Lattimore *et al.*, 2007, p. 138) (Newsom & Haynes, 2008, p. 288). However, Newsom and Haynes are clear that this is a guideline rather than an absolute rule.

> Of course, not every sentence should be short. An endless stream of short sentences make for dull reading. ... It is possible for long sentences to be clear if they are properly constructed. ... An occasional long sentence is no problem. But a never-ending series of long sentences leaves readers dizzy. According to Gunning, modern prose read by the public has an average sentence length of about 16 words. If your sentences are much longer than that on the average, your prose probably isn't as readable as it should be. (Newsom & Haynes, 2008, p. 110)

4.8.3 Jargon

Jargon should be avoided whenever possible (Anderson, 2006) (Lattimore *et al.*, 2007). When it can't be avoided it must be explained. "No one wants to have to use a science dictionary just to read an article" (Leite Vieira, 2008).

> If a word that has no plain English equivalent is essential to your subject, you have no choice but to use it. But make sure you explain to your readers what

> this new term means. ... your purpose is not to build the readers' vocabularies but to convey an idea. (Newsom & Haynes, 2008, p. 124)

4.8.4 A description is clearer than a definition

When dealing with jargon, there can be a danger of substituting definition for explanation. Simply using one scientific term to explain another, for example "fermions (particles that obey Fermi-Dirac statistics)" adds no information (Leite Vieira, 2008).

> It does little good to define kilowatt-hour as "the amount of energy consumed when an electrical demand of one kilowatt is maintained for one hour." You're much better off if you describe a kilowatt-hour as the amount of electricity it takes to run a hand-held hair dryer for an hour, or as the energy needed to toast three loaves of bread. These are not good scientific definitions of a kilowatt-hour, but they are good descriptions - and they're much more likely to be understood. (Newsom & Haynes, 2008, p. 124)

4.9 Clear writing

A number of authors offer lists of other desirable features that help to keep writing clear.

Hathaway's overview of the plain language movement for American lawyers identifies ten typical elements of plain English:

- a clear, easy-to-follow outline
- appropriate headings
- reasonably short sentences
- active voice
- positive form
- subject-verb-object sequence
- parallel construction
- concise words
- simple words
- precise words. (Hathaway, 1983, p. 945), in (Penman, 1993, p. 123)

Blunden suggests nine strategies to achieve a writing style which will engage a broad public audience "without sacrificing scholarship":

1. If the content is unfamiliar, use everyday language and take the space to explain your ideas properly. When a text has dense content you need to lighten its physical and linguistic density so the reader's conceptual space is not overloaded
2. Simulate the elements of spoken language. Use pauses, questions and variations in speed, volume, stress and rhythm to create a conversational style, echo the text and enhance meaning
3. Use familiar words. If less familiar or technical terms are important, take the time and space to define them properly. Use the more familiar term first, and then assist learning by repeating the new term in context, for example, 'smell (olfactory) receptors' and 'cocoa butter has to be specially cooled and reheated (tempered) during the process. Tempering maintains a high fat content ...'
4. Introduce your characters. A few extra words can include rather than exclude your readers, for example, 'convict architect Francis Greenway', 'critic and writer Robert Hughes' and 'American minimalist painter Barnett Newman'
5. Relate unfamiliar/complex ideas to the experience of the reader. This may require stretching your imagination, for example, 'Like people at parties, galaxies are found in groups ...'
6. Maintain a clear thematic structure in your paragraphs, even if this means using the passive voice. In English, the theme is always located at the start of the sentence or its principal clause
7. Use descriptive adjectives and adverbs to help make information/people more memorable and multi-dimensional, for example, 'the peppery Frederick McCoy' and 'clubs were enthusiastically established across Australia'.
8. Keep your principal clauses intact. Don't fragment the main idea with subordinate ideas/clauses, for example, 'born in Scotland in 1826, Marion Smith made this quilt from fabrics given to her by family and friends. After decades of loving use, she gave the quilt to her eldest granddaughter.', not 'Marion Smith, who was born in Scotland in 1826, made this quilt, which she gave to her eldest granddaughter after decades of loving use, from fabrics given to her by family and friends'.

9. Include the footnotes. You don't need to leave them out. You can also use footnotes as a way of layering information for 'mixed' audiences. (Blunden, 2006, p. 32)

Of the two, Hathaway's list is probably more relevant to this project. In a public outreach site, not sacrificing scholarship is only a minor concern.

Even taking this into account, neither of the above lists is definitive; nor is there complete consensus. For example, in contrast with point seven of Blunden's list, Newsom and Haynes advise minimising adjectives and adverbs (Newsom & Haynes, 2008, p. 288).

El-Awady warns of the dangers of taking point five of Blunden's list too far.

> Some metaphors have been over-used and are not always a good choice. Very often metaphors and comparisons in science writing are used wrongly. The images are not well chosen, describe only one part of a subject matter and may lead the audience on the wrong path. Some metaphors only make sense to those who understood the issue already, such as calling the genetic code the book of life. Metaphors are powerful tools that should be used with care. And very often it is better not to use them and just describe or explain things in another way. (El-Awady, p. 15)

For all the insistence on short sentences, Mohan recommends that "Structural links are built through a wise use of connecting words such as however, because and therefore" (Mohan *et al.*, 1997, p. 163).

In fact, Newsom and Haynes believe that the rules of clear writing are made to be broken.

> An occasional long sentence, if constructed properly, can improve the flow of the narrative. A compound sentence can take the reader from one idea to the next. An occasional inversion of subject and verb reduces monotony and can emphasize the action in the sentence (Newsom & Haynes, 2008, p. 114).

4.10 Readability is not the same as clarity

The emphasis on short sentences and short words has led to formulas to measure readability, especially those devised by Gunning and Flesch. Unfortunately, a high readability score does not necessarily mean that a document is easy to understand, but only that it is structurally simple (Charrow, 1979). As Gunning himself remarked: "nonsense written simply is still nonsense" (Gunning, 1968, p. 44). In the same vein, Penman quotes a slogan which holds that "brevity is no substitute for clarity" (Penman, 1993, p. 124).

Readability tests, then, can be a useful tool, but they are no guarantee of comprehension. Penman believes they do more harm than good, in that they "offer a potentially false promise of improvement, simply on the grounds that changing a document has led to a reduced reading age index" (Penman, 1993, p. 130).

4.11 Inverted pyramid structure

When writing factual articles for a general audience, the "inverted pyramid" structure is effective: starting by stating the main point, then supplying details and explanations once the reader understands the purpose of the article (Nielsen, 1997). "It is much easier for readers to follow a chain of explanations if they know the point of the story ahead of time" (Newsom & Haynes, 2008, p. 126).

It's also wise to keep the topic and theme in the reader's mind by referring to them frequently throughout the article (Mohan *et al.*, 1997, p. 163).

4.12 Informative titles and subheadings

A long article can be made clearer by the use of informative titles and subheadings. Titles should be worded so as to be useful to the reader, not the writer. "For example, we may write a heading 'Background to the study' while a reader would find the heading 'The need for soil analysis' more descriptive of the contents of that section" (Mohan *et al.*, 1997, p. 291). In other words, each title and sub-heading should inform the reader about the content of the paragraphs which follow. "Make the topic of each section and paragraph visually prominent by using headings and subheadings, and by placing topic sentences at the beginning of paragraphs" (Mohan *et al.*, 1997, p. 163).

4.13 Writing for the web

The recommended format of a factual article is similar whether it's intended for print or the Internet, but there are extra considerations when writing for the Internet. It is even more important to "hook" web readers, with a strong introduction, as soon as possible. "Make them wait more than 10 to 20 seconds and they'll bail out. Make them work to find the information they need and they won't return" (Newsom & Haynes, 2008, p. 286).

4.13.1 Web users don't read, they scan

Nielsen's article "How Users Read on the Web" begins with the warning, "They don't." (Nielsen, 1997). He goes on to suggest including the following features in web writing:

- highlighted keywords (hypertext links serve as one form of highlighting; typeface variations and color are others)
- meaningful subheadings (not "clever" ones)
- bulleted lists
- one idea per paragraph (users will skip over any additional ideas if they are not caught by the first few words in the paragraph)
- the inverted pyramid style, starting with the conclusion
- half the word count (or less) than in conventional writing (Nielsen, 1997)

Even once hooked, visitors to web sites do not take in information in the same way as readers of a newspaper or book. Web readers scan information rather than read (El-Awady, p. 26) (Yates, 2007). A Sun Microsystems study found that seventy-nine percent of site visitors scan websites for content, and only eleven percent read word for word. The same study also found that copy on the screen is about 25 percent more difficult to read than in printed form (Holtz, Undated), in (Newsom & Haynes, 2008, p. 287). This type of skim reading is best served by providing plenty of formatting cues: headings, topic sentences, diagrams and numbering systems (Mohan *et al.*, 1997, p. 163) (Newsom & Haynes, 2008, p. 299).

Lattimore *et al* include a similar list to Nielsen's, (above):

- Put blocks of no more than 75 words each on initial site pages. Longer text farther into the site is fine.
- Don't use clever headlines, but structure your articles with several levels of headlines so a reader can complete a section and continue reading or choose to move on.
- Write 50 percent less at the beginning of an article. Most Internet users scan copy before deciding to spend time in depth to read an article.
- Highlight keywords through hypertext links, typeface variations, or color.
- Use bulleted lists when the copy makes this possible. The computer screen is small, and people tend to glance at key elements quickly.

- Use inverted pyramid style for most copy with the most important information first. Don't bury your key points.
- Use one main idea per paragraph.
- Keep your sentences short, but on the other hand, remember that the key to a good Web site is that you have provided the answers to the questions that the reader has, so you need to be thorough. (Lattimore *et al.*, 2007, p. 139)

Although Lattimore *et al* are in favour of variations in typeface and colour to add emphasis, they make the point that this device should be used with restraint, as too much variation in typeface can be a hindrance to reading (Lattimore *et al.*, 2007, p. 140). In other words, all formatting should be meaningful: there should be no redundant use of different typefaces. It's also important to make a clear distinction between emphasised text and hyperlinks: any text which might be taken for a hyperlink should actually be a hyperlink.

> Use restraint if you want to emphasize a point. ... Italicizing, boldfacing, underlining and all caps ... should be used to complement the message, not compete with it. Overuse of these devices also impedes readability and reading. We suggest you use underlining rarely because visitors will assume it's an inactive link. (Newsom & Haynes, 2008, p. 289)

Formatting should also be consistent throughout the site, as consistency helps users find information (Lattimore *et al.*, 2007, p. 140).

When writing for the web, it's especially important to group ideas together, and provide informative subheadings, not "clever" ones. Readers should be able to get the gist simply by scanning through the paragraphs while scrolling (El-Awady). At the same time, headings should be made interesting, to encourage users to read on. Readers will skip a paragraph, or even leave the site altogether if they don't like a heading. A web page is always in danger of losing its audience (Yates, 2007).

4.13.2 Short sentences, short paragraphs, short articles

Web articles should be kept shorter than print articles.

> Reading long text from a computer screen is tiring for the eyes. Most people leave long text articles for when they are reclining in a chair or sipping tea at the breakfast table. So although the internet does have the advantage of limitless

space, people will only read your article if you keep it short and sweet. (El-Awady, p. 26)

Yates recommends one point per paragraph, and one paragraph per sub heading. He says that web writing should sacrifice flow in order to be terse, short and sharp (Yates, 2007).

According to Garrand, the recommendations to use short paragraphs and bulleted lists apply especially on the first few levels of a web site, where users are still trying to locate the material they want. Once they have found the correct information, users are often content to read a longer, more complex article (Garrand, 2001, p. 18).

4.13.3 Web users don't like to scroll

Yates is prepared to countenance as much as three screens' worth of text on each web page (Yates, 2007), whereas Lee recommends that each page should be as close to one screen as possible (Lee, 2003). Peter Wrobel warns that sub-editors "have to work on the general assumption that ... 90 per cent [of readers] will not touch the scroll button when reading an article online." (Wrobel, 2008)

Of course "one screen" can only be a rough measure: a site's designer has no means of ascertaining or controlling a user's screen size or resolution. As a general guide Lattimore *et al* suggest column widths of 200 to 400 pixels, and page lengths of twenty to forty-four lines (Lattimore *et al.*, 2007, p. 140).

4.14 Hyperlinks

4.14.1 Advantages of hyperlinks

The most significant difference between web writing, and writing for print, is the presence of hyperlinks. Amongst other uses, they allow definitions and explanations to be accessed immediately, whenever a term is mentioned, without interrupting the flow of the writing.

The CAMS website has to cater for a wide range of educational backgrounds, so it must continually explain or define concepts for those who know little science, without alienating the more knowledgeable. Hyperlinks allow explanations to be contained in separate pages or pop-ups, which do not interrupt the narrative flow. Similarly, more-complex topics can be set aside from the main theme, so that the less knowledgeable (or less interested) can skip them and read on.

4.14.2 Quantity of hyperlinks

Hyperlinks are a very powerful tool, in that they allow multiple connections between topics to be made explicit, but this extra complexity can become overwhelming if taken too far. A design which contains too many choices can be bewildering, and can discourage the user from reading topics in a logical order. Each link introduces the danger that readers will click on the link without reading the rest of the page (Yates, 2007). "A failure to control this complexity can lead to cognitive overload and failure to learn" (Ambron & Hooper, 1993, p. 127).

Ambron and Hooper found that hyperlinks could be useful in web-based learning, but recommend limiting the number of choices available on the screen at any one time. In their view, "seven, plus or minus two, is optimal" (Ambron & Hooper, 1993, p. 128). In fact, Ambron and Hooper do not appear to adjust this number to allow for the quantity of information on the page, for the complexity of the material, or for the audience's familiarity with the topic. In my opinion, seven links is excessive for a short page attempting to explain a complex topic to a general audience, so there are fewer links on each page of the CAMS public outreach site.

4.14.3 Wording of hyperlinks

Hyperlinks should never consist simply of the words "click here" (Yates, 2007). Whether long or short, a hyperlink should be meaningful.

> Introducing informatively worded hyperlinks in the text of a web page encourages more link clicking overall and increases comprehension. Introducing intriguingly worded hyperlinks in the text of a web page encourages more embedded link clicking, which may be desirable for site designers who want their visitors to explore more of the site – and perhaps go to places they never would have thought to go to via links in the navigation menu. (Wei *et al.*, 2005, p. 443)

Opinion is divided over whether to make links informative (and therefore longer) or succinct (and therefore less descriptive). Lee states that links should be concise, and prefers them to be no more than three words long (Lee, 2003). Conversely, Lattimore *et al* believe that links should describe their target pages, so users can decide whether to click on them or not (Lattimore *et al.*, 2007, p.

140). Wei *et al* offer a compromise: "Designers who wish to use informative or intriguing hyperlink wording should reserve such strategies for embedded hyperlinks within a web page and not employ such methods with hyperlinks in the navigation menu" (Wei *et al.*, 2005, p. 443).

4.15 Clear writing revisited: simple language doesn't imply that the audience is stupid

As discussed above, Web readers skim and scan articles, skipping any sections which don't immediately hook their interest, and following hyperlinks at will. Sections, paragraphs, sentences, and even words, have to be short. Writing has to get directly to the point. Newsom and Haynes stress that "This does not justify sloppy writing. In fact, this behavior demands the best, most precise and concise writing. The point is to deliver copy in smaller chunks, not necessarily to write half as much copy" (Newsom & Haynes, 2008, p. 287).

In the words of Leite Vieira , "Simple language is not incompatible with rich content" (Leite Vieira, 2008). Dr Jonathan Hare of the University of Sussex advises that science communicators should not think that their audience is stupid, but should strive to get the language right: "The answer isn't to make it simple. You should keep it quite hard, but give it in a language that people can understand" (Office of Science and Technology, p. 11). The magazine *Planet Earth* advises its scientist authors to imagine trying to explain their science to a fourteen-year-old, and points out that this is not patronising: fourteen is the reading age of *The Times* and *The Guardian* (Natural Environment Research Council, 2008).

Finally, this is not poetry: the object of the exercise is to communicate the science. "Even if you think the audience is more sophisticated, don't be tempted to make the language difficult. Science is hard enough without having to think about the words" (Stocklmayer, 2001, p. 18).

4.16 Summary of literature review part 2: writing, and web writing

Any writing which nobody reads has failed, so it's vital to create material which will appeal to your intended audience. The content has to be relevant to your audience's life, and pitched at a level appropriate to your audience's knowledge. Your readers have come to you voluntarily, and can leave as soon as they lose interest, so your writing must engage their enthusiasm.

Web readers in particular have a famously short attention span, and for them distraction is only a click away, so web writing must get straight to the point.

Web readers can enter a site at any random point, and may choose to read all or part of the site in any order. A clear structure will help them orient themselves and make sense of what they are reading. Headings should signpost the structure and content of the material, so readers can scan the page to see if they want to read it.

The language, the style and the structure are all just means to an end, so they should be as simple and transparent as possible. Anything which does not serve to communicate the message is redundant.

5 Putting this project in context

5.1 A review of some educational websites dealing with antimatter

5.1.1 Date of the review

This review was conducted in February 2009. It's in the nature of websites to be updated continually, so some information may now be out of date.

5.1.2 NASA

NASA is the American National Aeronautics and Space Administration.

The NASA website has a few pages about antimatter. They're professionally produced, with a clean, fairly modern look and feel, which could be adapted (or simply updated a little) by CAMS (NASA, Status of Antimatter) (NASA, New and Improved Antimatter Spaceship for Mars Missions).

The writing is quite specialised, and largely to do with the practicalities of antimatter propulsion. This is not a place to start learning about antimatter. Still, the style is readable: casual and friendly but grammatical.

A number of pages on the NASA site refer to antimatter, but the only real way to navigate around them is with a search engine. NASA doesn't really have an antimatter section as such, so structure and navigation is irrelevant.

5.1.3 How Stuff Works

(How Stuff Works)

How Stuff Works was founded by North Carolina State University Professor Marshall Brain in 1998. Its stated aim is to "demystify the world and do it in a simple, clear-cut way that anyone can understand" (How Stuff Works), although *How Stuff Works* also carries consumer opinions and reviews of consumer products. It was among *Time Magazine*'s *25 Web Sites We Can't Live Without* in 2006 and 2007, and has been one of *PC Magazine*'s *Top 100 Web Sites* four times, including 2007. *How Stuff Works* is now a wholly-owned subsidiary of Discovery Communications.

The site is visually attractive, although marred by the advertising that's inherent in a commercial website. It's cleanly and efficiently written: every word is made to count. It assumes a fairly high level of technical knowledge, although this is excusable on a site such as *How Stuff Works*, which will have explanations of many of its technical terms elsewhere.

The antimatter section of *How Stuff Works* doesn't make full use of the huge glossary it has at its disposal: terms such as electron and proton are introduced with no explanation, or link to a definition. In the site's defence, it should be noted that this does help to keep the page uncluttered, and that web designers should think about limiting the number of links on each page, even if they are only links to a pop-up glossary (Ambron & Hooper, 1993, p. 127).

The antimatter section of *How Stuff Works* is very small: a single module consisting of three linked pages, so the question of navigation doesn't arise.

The site fits a lot of information into just three screens, so the information density is high for a lay audience. The CAMS readership might well be encountering many of the terms in this material for the first time, so a slightly lower information density would be better suited to CAMS. Otherwise the style is quite appropriate to CAMS' public website: chatty but informative, with some dramatic pictures.

5.1.4 About.com

About.com was founded in 1996, and since March 2005 has been owned by The New York Times Company (About.com).

About.com's antimatter section is highly technical material, from the first page, but it's written in a friendly, approachable style. The sequence of ideas is presented well, but the effect is lost, as there are far too many links on each page. There are so many links that it becomes difficult to follow the thread of the article (Ambron & Hooper, 1993, p. 127).

Visually, the site is dreadful. It's swamped in advertising: less than half the screen is available for the text, and much of the advertising uses the same typeface and colour scheme as the text. It can be distracting to have to keep track of which paragraphs form part of the article and which do not, at the same time as absorbing complex new information. In my opinion, many readers will simply give up and go elsewhere.

Fortunately, articles on the CAMS site will not have to jostle with advertisements, but this is a good reminder to keep the layout of the site clean, and guide the reader's eye to scan the page in the correct order (Yates, 2007).

5.1.5 Space.com

Space.com is published by Imaginova, an American company which is also responsible for a variety of news, science and general-interest websites, including *NewScientist.com.* (Space.com)

Space.com's colour scheme is garish, and its layout manages to be both cluttered and wasteful of space. The writing style is similarly rambling. In the first paragraph the article on antimatter mentions "brain scans" in passing, with no explanation, then returns to the topic just once, equally briefly, paragraphs later. There's no sense of where the article is going, or why. The paragraph headings are both meaningless and uninteresting: they neither guide the reader through the article, nor intrigue him or her enough to read on.

This is a brave attempt to cram a great deal of information onto one page, but at the same time there's too much extraneous detail:

> One example is when a high-energy proton in a solar flare collides with carbon, Share explained in an e-mail interview. 'It can form a type of nitrogen that has too many protons relative to its number of neutrons.' This makes its nucleus unstable, and a positron is emitted to stabilize the situation. (Space.com)

Who cares about the email? The reader wants to know about antimatter, not how the interview was conducted.

This site is really only relevant to CAMS as an example of what not to do: it could benefit from a clearer picture of its audience, a better focus on exactly what information it does (and does not) intend to convey, and more thought about its structure.

5.1.6 The European Organisation for Nuclear Research (CERN)

(CERN, Antimatter: mirror of the Universe)

CERN is the European Organisation for Nuclear Research. Founded in 1954, it was one of Europe's first joint ventures, and now has twenty Member States.

CERN's outreach site *Antimatter: Mirror of the Universe* has an attractive home page: the site has won numerous awards, although they were nearly all awarded almost a decade ago.

There's an informative glossary, but it directs the browser away from the page where the technical term occurred. A pop-up window would be less disruptive of the flow of the article.

The *Questions and Answers* section has been edited well. Despite the rather slapdash sub-editing (there are numerous typographical errors) it's readable and informative.

The *For Kids* section has been written by a single author, who obviously knows her audience. It's sequential, clear and consistent.

The *Antimatter Academy* section is a little more uneven. It begins by promising, "These pages will enable you to travel beyond the borders of reality and visit unknown worlds. In each trip, you will discover different aspects of antimatter" (CERN, Antimatter Academy), but then appears to forget about this theme. Instead, visitors to the site are immediately sidetracked to the "briefing room" to read about Einstein and learn that $E=mc^2$. It's good information, explained well, but visitors aren't told why they're suddenly reading about energy being the "money of nature". Some more signposts about the point of the article would not go amiss.

Some of the *Antimatter Academy*'s analogies can be a little clumsy. El-Awady warns against using analogies and metaphors which will only make sense to readers who already understand the issue (El-Awady, p. 15). Describing energy as the "money of nature" may well fall into that category, as may comparing an antiparticle to a hole in a sheet of metal.

Later in the *Antimatter Academy* section, there's a single article following the promised "trip" theme, but *Back in Time to the Big Bang* appears to have been written as an audio script for some other purpose, and then simply transcribed onto the site. There's no other reason to introduce, suddenly and awkwardly, a "teen-age girl scientist" and "teen-age boy". It's an unexplained change in pace and style, adds nothing to the communication, and the script format only makes the reading harder.

At the end of this section, there's no clue where to go next.

As the reader progresses into the site, the language and concepts very quickly become more complex. In my opinion, few users who enjoyed the introduction will read to the end, while those who might appreciate the later sections will probably be put off by the simplistic introduction.

There's a little too much "name-checking". A casual visitor, looking for an introduction to antimatter, doesn't care that:

> The goal was simultaneously achieved by two teams of physicists, one led by Antonino Zichichi, using the Proton Synchrotron at CERN, and the other led by Leon Lederman, using the Alternating Gradient Synchrotron (AGS) accelerator at the Brookhaven National Laboratory, New York. (CERN, The History of Antimatter)

That information has its place, but it doesn't belong in a public outreach site.

Overall the quality of the writing is good, but inconsistent. Many different authors have contributed text, and the site would benefit from a supervising editor.

It's not an easy site to navigate, but it would be simple to solve the problem by revising the menu.

The layout can be a little dull. There are lots of small, black and white photographs, arranged in a single column away from the text, and the site now feels quite dated. (It is, after all, almost ten years old.)

The CERN site has some excellent content, spoilt only by lack of attention to its presentation. The CAMS site can benefit from the CERN example, but should strive for better images, a better menu and a more even tone.

5.2 A best-practice review of online public outreach by the client's peer organisations

5.2.1 Overview of the client's peer organisations' communication

Most of the fifteen Australian Research Council Centres of Excellence reviewed here make some attempt at public outreach, but this often takes the form of workshops for schools, exhibits, public demonstrations, or events during Science Week.

Only a minority of ARC centres have public outreach material directly on their website. Of those that do, several seem to have provided this material as something of an afterthought: there is a preponderance of PDFs of pre-existing documents. Of course this is better than nothing, but the PDF format is not especially web-friendly.

Some sites have links to external information resources. Done well, this can be a detailed list of recommendations, arranged and categorised, as has been provided by the Centre of Excellence for Coral Reef Studies. Done less well, a links page might be no more than a few links to Wikipedia (as found for example on the site of the Centre of Excellence in Design in Light Metals). Where the links are genuine recommendations, by somebody who has investigated and evaluated each linked site, then a page of links can be useful in pointing the user towards appropriate material. Otherwise, it isn't clear what benefit a page of links provides: a simple Google search can return a list of sites. In the case of one or two of the sites reviewed here, the reader might well conclude that this is how the pages have been generated.

Several of the sites betray the fact that public outreach is not high on their owners' list of priorities, through the classic signs of a lack of maintenance: publicity for events that are long in the past, broken links, or planned sections that appear in the menu but have never been realised.

A few centres have provided some good, original information, appropriate for public outreach, in a reasonably web-friendly format. **Those sites are marked with an asterisk below.**

CAMS' existing site is already one of the better sites, in terms of online public outreach.

At the time of writing, no ARC Centre of Excellence has even attempted online public outreach comparable to the new CAMS site.

5.2.2 Date of the review

This review was conducted in February 2009. It's in the nature of websites to be updated continually, so some information may now be out of date.

5.2.3 The sites

5.2.3.1 ARC Centre of Excellence for Coral Reef Studies

(ARC Centre of Excellence for Coral Reef Studies)

There isn't much educational material directly on this site, but under "educational resources", there are numerous links to other sites, grouped by category and recommended age group.

5.2.3.2 ARC Centre of Excellence in Structural and Functional Microbial Genomics

(ARC Centre of Excellence in Structural and Functional Microbial Genomics)

There's very little educational material on this site.

There are some press releases, featuring over-used words like "breakthrough" in their titles. On closer inspection, a press release entitled *The science of genomics explained* turned out to contain little more than the date and time of a single lecture.

The *Education* tab was simply a list of PhD projects.

5.2.3.3 ARC Centre of Excellence in Design in Light Metals

(ARC Centre of Excellence in Design in Light Metals)

This site has attempted some public outreach, but appears to have given little thought to its audience.

The home page has a link to a PDF promotional brochure, and another to a long, repetitive video. Money has clearly been spent, but this is no guarantee of successful communication. The video's production quality is high, but its content is little more than a series of images of indistinguishable machinery. This is set to a soundtrack that consists of a stream of passive verbs and jargon, recited by a professional, but patently uncomprehending, voice-over artist. I don't believe anyone will have watched it to the end.

The *Fact Sheets* section, under *Educational Resources*, consists entirely of three links to Wikipedia.

5.2.3.4 ARC Centre of Excellence in Plant Energy Biology

(ARC Centre of Excellence in Plant Energy Biology)

This centre has physical outreach activities, including workshops, and an interactive booth which they take to science festivals, but none of the content is online.

There's some information on their website under *Research*. It's not badly written, but it's too technical for a general audience.

There are some quite good teachers' notes, but (as might be expected) they need interpretation for a general audience.

5.2.3.5 Australian Centre for Plant Functional Genomics

(Australian Centre for Plant Functional Genomics)

This centre runs some workshops for school students in Adelaide, and appears to do a significant amount of real-world community outreach. It isn't clear whether the content of these workshops is online.

Online, they do have some PDFs about their work, which are simple to understand, but which have the look and feel of commercial promotional material. The centre strongly promotes genetically modified crops, and the website simply ignores the issue of negative consequences, so an advertising-style approach is unlikely to help its credibility.

In February 2009, the centre says that it is redeveloping its website. No estimated completion date is given.

5.2.3.6 ARC Centre of Excellence for Creative Industries and Innovation

(ARC Centre of Excellence for Creative Industries and Innovation)

This site has a high-tech look and feel, but is clearly aimed at corporate clients. There appears to be no public outreach at all.

5.2.3.7 ARC Centre of Excellence in Ore Deposits

(ARC Centre of Excellence in Ore Deposits)

This site has a very corporate, commercial look and feel. There doesn't appear to be any attempt at outreach.

5.2.3.8 ARC Centre of Excellence for Electromaterials Science

(ARC Centre of Excellence for Electromaterials Science)

There's no sign of any outreach material. There's a menu tab labelled *Educational Resources*, but it doesn't lead anywhere.

5.2.3.9 National ICT Australia

(National ICT Australia)

This centre has a summer scholars program, and other real-world outreach activities. They're developing some commercial short courses, but there's no outreach material online.

5.2.3.10 Mathematics and Statistics of Complex Systems (Australian Mathematical Sciences Institute, AMSI)

(Mathematics and Statistics of Complex Systems (Australian Mathematical Sciences Institute))

There's no outreach on the website. They appear to do no outreach at all, other than in collaboration with the ARC Centre of Excellence in Coherent X-ray Science, during Science Week.

5.2.3.11 ARC Centre of Excellence in Coherent X-ray Science

(ARC Centre of Excellence in Coherent X-ray Science)

The site refers to the centre's having given some public lectures at retirement villages, as a part of National Science Week, in collaboration with two other ARC Centres of Excellence: the Centre for Free Radical Chemistry and Biotechnology, and the Australian Mathematical Sciences Institute. None of the content of these lectures is online.

The centre has made an effort to generate some material suitable for a school or public audience. A year-eleven student, we are told:

> ...visited Leann Tilley's laboratory in the Department of Biochemistry at La Trobe University for one week ... She generated a series of interviews with CXS members asking them questions that might be of interest to high school students. Read her interviews. (ARC Centre of Excellence in Coherent X-ray Science)

Sadly, the link is broken, and there's nothing else suitable for the public.

5.2.3.12 *ARC Centre of Excellence in Vision Science

(ARC Centre of Excellence in Vision Science)

This site has a plain, uncluttered design.

There are several pages of simple explanation of the centre's aims and research. It gets technical quite quickly, but the introductory pages are well written.

The centre also has an exhibit at Questacon, the National Science & Technology Centre in Canberra, but there's only a paragraph or so about it on the website.

5.2.3.13 * ARC Centre of Excellence for Free Radical Chemistry and Biotechnology

(ARC Centre of Excellence for Free Radical Chemistry and Biotechnology)

There's a brochure, in PDF form, under *community*. It's well written, although maybe a little too technical, and very short. Unfortunately it's badly laid out for the web, and difficult to print. What's more, there are links to the same brochure, with different titles, in several different places. This sort of irritating detail is likely to drive away the notoriously fickle web audience (Yates, 2007).

The centre makes an attempt to show the scientists' human side, with a few "day in the life" questions, but when they talk about their science it's nearly always too technical for a general audience.

This centre has (like the ARC Centre of Excellence in Coherent X-ray Science) invited year-eleven students to shadow researchers and write a report, and one of these reports is available on the website. It serves to humanise the centre to some extent, but (given that it was written by a year-eleven science student) it could have benefited from some sub-editing: it isn't as informative as it could be. As an outreach exercise this will have been of more interest to the particular student's school than to general visitors to the site.

5.2.3.14 * Australian Stem Cell Centre

(Australian Stem Cell Centre)

This site has some very good public education fact sheets, available to download in their original form. Some of the fact sheets have been adapted to web viewing, and where it's been done, it's been done quite well, but it isn't clear where the two media overlap.

Generally the web content appears less detailed than the fact sheets. The web content is fairly technical, but there's an acceptable glossary. Unfortunately the glossary isn't a pop-up: it redirects the browser away from the page where the term appeared.

There's also a good page of external links to other stem cell information.

At the time of writing, this is the best online public outreach of the ARC centres surveyed here (with the possible exception of CAMS' existing site).

5.2.3.15 * ARC Centre of Excellence for Antimatter-Matter Studies (CAMS)

(ARC Centre of Excellence for Antimatter-Matter Studies) This is already one of the best online public outreach sites among the ARC centres. In particular, the answers to the Frequently Asked Questions are very well written, though the presentation is visually a little dry.

Fortunately for the future of this project, there's still room for improvement!

6 Research methods

6.1 *Establishing the client's requirements*

CAMS approached the Centre for the Public Awareness of Science (CPAS), with the idea of using CPAS' science communication resources to develop some outreach projects, and the intention of sponsoring one or more Master of Science Communication projects to this end.

Dr Rod Lamberts (from CPAS) and I met CAMS' Chief Operations Officer and Research Director, to discuss what could be achieved. At this first meeting we considered CAMS' existing communication material and talked about how best to promote CAMS to the public. CAMS had various suggestions, including:

- An exhibit to be installed at Questacon, The National Science & Technology Centre in Canberra;
- A presentation or web site aimed at schools;
- A package of information kits and displays to take to schools;
- An information section about antimatter, aimed at the public, to be added to the CAMS website;
- A public lecture.

This was clearly too much work for a single Master of Science in Science Communication sub-thesis, and we recommended covering a small section of it thoroughly, rather than trying to address too disparate an audience, through too many media at once. We offered to work with the client to identify a few areas that could reasonably be developed within the scope of a Master's project.

I recommended that the medium shouldn't be chosen at random: it should be selected to suit the information content and audience. In particular we decided against the "brochures for schools" option, on the grounds that:

- We believe that teenagers are more likely to visit a website than read a brochure;
- It's cheaper and easier to adapt and update a website than a printed brochure.

I stressed the importance of evaluation. It's all too easy to write and deliver a lecture from a scientist's point of view, without finding out if the subject matter is really comprehensible to the public, or meets the audience's requirements. Stocklmayer recommends starting a communication project by considering the following:

- What does your audience want to know?
- What do they already know?
- What are their existing beliefs about your information? (Stocklmayer, 2007)

However, in this case, and in consultation with the client, we agreed that evaluation of the communication would have to fall outside the scope of the current project. Establishing the content, writing text, selecting illustrations, obtaining permissions from copyright holders, commissioning artwork and animations, and developing and implementing a fully-functional website was a considerable amount of work in itself, which precluded spending additional resources on evaluation.

6.2 Parameters

The process of gathering data for the website's content was deliberately open-format, consisting of a series of semi-structured interviews.

I conducted some "best-practice" reviews of similar websites, and was able to offer advice and consultancy about web design, and about science communication practices, but I was also required to take the client's specific wishes into account.

This is not a pure research project. Instead, I was commissioned to create an artefact. The purpose of the project was not only to create communication material according to the principles of current science communication theory, but to produce a practical artefact which met the client's real-world requirements.

6.3 Preliminary data gathering: interviews with the client

According to Stocklmayer, communication can be for several distinct purposes, including:

- Information transfer;
- Awareness raising;
- Dialogue;
- Obtaining support from your audience;
- Changing behaviour;
- Adoption of results. (Stocklmayer, 2007)

She suggests starting by asking the questions:

- What do you want your audience to know?
- Why should your audience want to know it? (Stocklmayer, 2007)

After a meeting with CAMS' Chief Operations Officer and Research Director, to establish their broad requirements, I began consultations with CAMS' Research Director, in order to determine a target audience and some key messages. We also needed to establish the balance between various potentially conflicting priorities, for example:

- Is the primary intention to educate?
- Is the primary intention to create a positive image of science?
- Should the emphasis be on the science of antimatter, or on CAMS' own research?

I approached the consultations with a series of questions, informed by my own knowledge of physics (from my honours degree) and of science communication practices. The consultations were in the form of semi-structured interviews, aimed at answering specific questions, but also leaving open the option of introducing any other material the interviewee considered important. My initial questions were as follows:

- Does CAMS want the emphasis on its own research, or general information about antimatter?
- What are the important issues in antimatter, and why?
- Why should the public care about antimatter?
- Where does CAMS fit into the context of worldwide antimatter research?
- Why is CAMS' research important or exciting?
- What would CAMS like to see as a result of this outreach? For example, increased public interest in antimatter, increased public understanding of science, increased government funding, an increased number of applications to study at CAMS?
- How will the outcome be evaluated?
- Does CAMS have a preference for a particular style of artefact?

So that note-taking wouldn't interfere with the interview process, I made audio recordings and distilled these into notes to be approved later by the client.

My role at this stage, as facilitator of the information-gathering process, was not to influence the content, but to establish the key issues which the client wished to communicate. For this reason, I chose open-ended questions, which allowed the interviewee to talk. Rather than a structured interview, designed to obtain a tightly-controlled answer to a researcher's own question, this approach was more likely to lead to a complete picture of the client's requirements.

The interviews covered more ground, and in more depth, than would be suitable for a lay audience. I was able to use my education in physics to obtain background information, in order to provide myself with a context for the communication material. Newsom and Haynes advise:

> You must understand [complex material] thoroughly yourself before you can explain it to somebody else. You must know more about the subject than you'll ever put into print. If you don't, you won't be able to tell when a simplified statement can stand alone or should be qualified. And you won't know the difference between a correct statement and a false one. (Newsom & Haynes, 2008, p. 118)

At the same time, it was important to keep the audience in mind throughout the interview process. According to the World Federation of Science Journalists, "Part of the answer to better writing is insisting during interviews that the scientists simplify the science for you. ... If you don't understand something, say so. Never write about something you only half understand" (El-Awady, p. 15).

6.4 Difficulties with the interview process

At later interviews I presented CAMS' Research Director with a list of key points established in the course of our earlier brainstorming sessions, and asked him to prioritise. This was by far the most difficult stage of the process. He is an enthusiastic communicator, and was keen to convey a huge amount of information, in too much scientific detail for a lay audience. On numerous occasions material which we had agreed to simplify (or even omit altogether) resurfaced some time later as one of his top priorities, and had to be accommodated in one form or another. This is a good illustration of one of the differences between a pure research project and a commissioned artefact. It can be difficult to persuade a committed stakeholder to prioritise, and sometimes in practice there's no choice but to accept some of the limitations of the situation: a project which alienates its chief stakeholder is unlikely to succeed.

6.5 Content and structure

During an early interview CAMS' Research Director mentioned that he was committed to deliver a public lecture quite soon, for which he needed a script and a PowerPoint presentation. We realised that the key messages and target audience would be broadly the same for all the outreach activities we had considered, so we decided to create a set of core content that could be easily adapted for various media, concentrating initially on the lecture and the web content. We agreed that I would provide consultancy in the preparation of the talk, as a method of identifying and developing core content suitable for general outreach projects. The information gathered during this process could thus be used as the basis of the lecture, the website and other outreach projects.

6.6 *Target audience*

CAMS' Research Director's target audience was "the public" (all ages and all education levels) and it proved difficult to narrow this down. He mentioned when pressed, "School teachers, interested scientists, and interested members of the public." He went on to say that he also wanted to include some material pitched above this level, "for physicists or chemists, who might appreciate something that wasn't pitched at the year-twelve level." In a later interview he said that his idea of a typical visitor to the site "...is not Joe Average – but design the site around Joe Average." In the same interview he said that the "common denominator" should be a year-twelve education, and that visitors shouldn't leave the site feeling that they hadn't learnt anything.

This isn't necessarily a standard definition of "public", but it's important to remember that the communication material was commissioned, and that the client organisation is entitled to choose its target audience. This is an example of the tensions between theory and practice that can arise in a commissioned, practical (rather than pure research) project: the purest theory does not always articulate fully into practice.

6.7 *The public lecture*

After a series of interviews, over approximately six weeks, we arrived at a fifth draft of the public lecture. Using an iterative process of writing, reviewing and re-writing each draft we had identified the core content that would form the basis of both the lecture and the website, assembled it into a series of broad themes, and arranged these into an order that would make sense to a lay audience. CAMS' Research Director gave the presentation at James Cook University, and handed out a survey form (see "Evaluation tool", page 68) to gauge the audience's reaction.

6.8 *Evaluation tool*

Before the first lecture I raised with the client the possibility of creating a set of evaluation tools to enable CAMS to measure the effectiveness of the talk.

In parallel with the initial talk, I provided some advice on a preliminary audience survey. This consisted of eight open-ended questions, intended to evaluate the audience's expectations and experience of the talk, followed by two or three questions about each respondent's background and knowledge of science. This initial survey was to be handed out and administered by CAMS staff at the first one or two lectures, and I hoped that the information gathered could be used to improve the talk's relevance to the public, and also to sharpen the focus of later versions of the survey itself.

Unfortunately it turned out not to be feasible to develop this idea fully, as almost all respondents to the survey seemed to be either science students, recent former science students or teachers of physics. We realised that this situation would not enable us to evaluate the talk as a tool for communicating specifically with the lay public, but time and budget constraints made it impractical to give the talk outside a university science environment. The first four performances of the talk were held at:

- The Physics Department of James Cook University;
- The annual meeting of the Australian Institute of Physics, held at the University of Adelaide;
- The Belgrade Science Fair;
- The Centre for the Public Awareness of Science at the Australian National University.

Nobody was available to conduct the survey in Adelaide or Belgrade, so it was only possible to collect data at James Cook University and the Centre for the Public Awareness of Science.

Although all the talks were open to the public, and most were advertised to some extent in the local media, it seems that only members of the scientific community attended the talks at which data could be collected. Once again, the client and I had to agree to accept this as an example of the differences which can arise between theoretical best practice and the reality of a budgeted, commissioned artefact. We can only speculate as to whether the wider community felt that a lecture taking place in a scientific institution was irrelevant, intimidating or simply of no interest. This might be a subject for a future thesis in itself.

Had the focus of the project been different, or its scope and resources significantly greater, it might have been possible to organise other venues with a wider audience, such as community centres, Lions clubs or Probus clubs. Unfortunately this is not a trivial matter: identifying potential audiences, estimating levels of interest, "selling" the talk to a venue manager, arranging dates, times and public liability insurance, and then publicising each event would have involved a significant amount of an administrator's time. The resources simply weren't available to do this work, so detailed evaluation of the lecture with a large, representative, public audience will have to wait for a future project.

This limitation doesn't invalidate the rest of the project. The client had been made aware that the audience was not likely to be a true representation of the population, but had nevertheless approved the limited range of venues.

We decided therefore to use the final draft of the initial talk as the basis for developing the other communication material, and to include some further evaluation in the next stage of the process, by adding a feedback form to the website.

A blank copy of the audience survey form is included below as "Appendix: CAMS audience survey". See page 83.

In all, thirty-six audience members responded to the audience survey, and respondents showed interest in the following topics.

Table 1. Topics from the public lecture, arranged in order of popularity (as measured by the audience survey)

Topic	*Positive Responses*
Medical applications of antimatter	13
Practical applications (unspecified) of antimatter	9
Positronium	8
Fact or fiction (including science fiction, antimatter weapons, antimatter as an energy source, antimatter spacecraft, etc.)	7
Anti-atoms	5
Discovery of antimatter, and history	2
Storage of antimatter	2
What antimatter is	1
TOTAL POSITIVE RESPONSES	47

Note that some respondents mentioned more than one topic; others did not refer specifically to any.

Generally respondents were extremely positive, perhaps even a little too polite. There were only two negative comments, and both happened to be about the most popular topic: the medical applications of antimatter. One negative comment came from an astronomy graduate who had wanted to hear more about antimatter in space; the other from a postgraduate physics student who had wanted more discussion of the generation of sub-atomic particles. Each said that they enjoyed hearing about the medical applications, but felt that some of the time spent on this topic could have been devoted instead to their particular interest.

In fact, even allowing for the restricted sample, a few trends were evident in the audience's responses.

- There was a great deal of interest in the medical applications, and other practical uses, of antimatter.
- Positronium caught the attention of many people in the audience (often those who had studied sciences other than physics).
- The "fact or fiction" approach to antimatter weapons, antimatter as an energy source, and antimatter spacecraft, also proved fairly popular.

This is really only anecdotal evidence, but it was better than no data at all when starting to plan the structure and character of the communication material.

As the survey is repeated and developed, it will be possible to add more specific questions. The survey already asks about respondents' educational background, but it might also be instructive to ask their age, and test hypotheses such as:

- Are younger people more interested in positronium, or science fiction, than older people?
- Do older people prefer to hear about medical applications?

Further evaluation of the communication material in both the lecture and the website might be a suitable topic for future research.

7 Results: the artefact

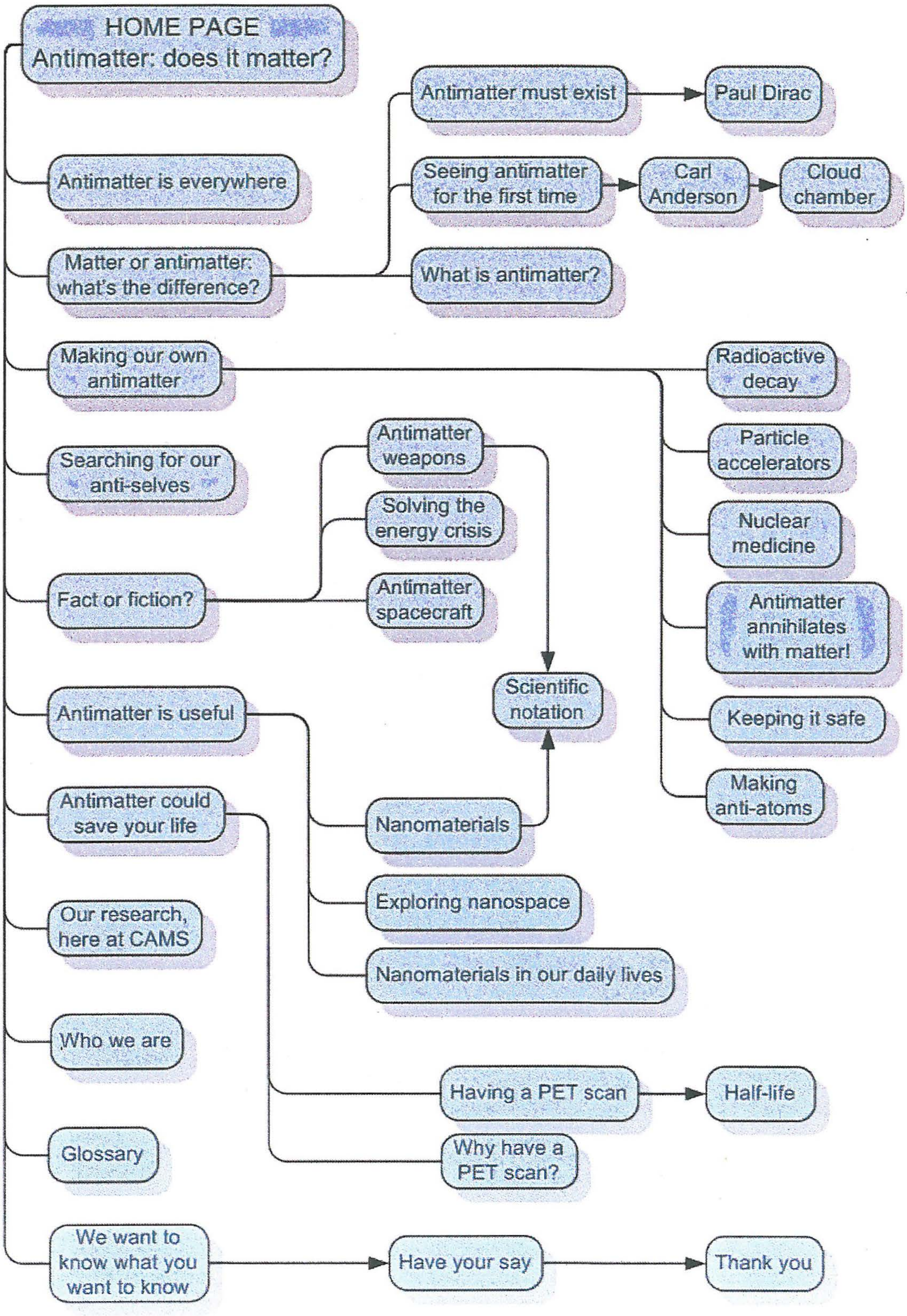
7.1 Communication material: the artefact itself

The artefact, as delivered to the client, consists of thirty-six pages (including pop-ups, the glossary and the survey) of text, illustrations and animations.

7.1.1 Site map

There is no online site map, as visitors to the site are intended to discover its content by following links and exploring, and should have no need of a site map in order to do so. However, a site map is provided below for reference.

Figure 2. Site map



7.1.2 Example pages

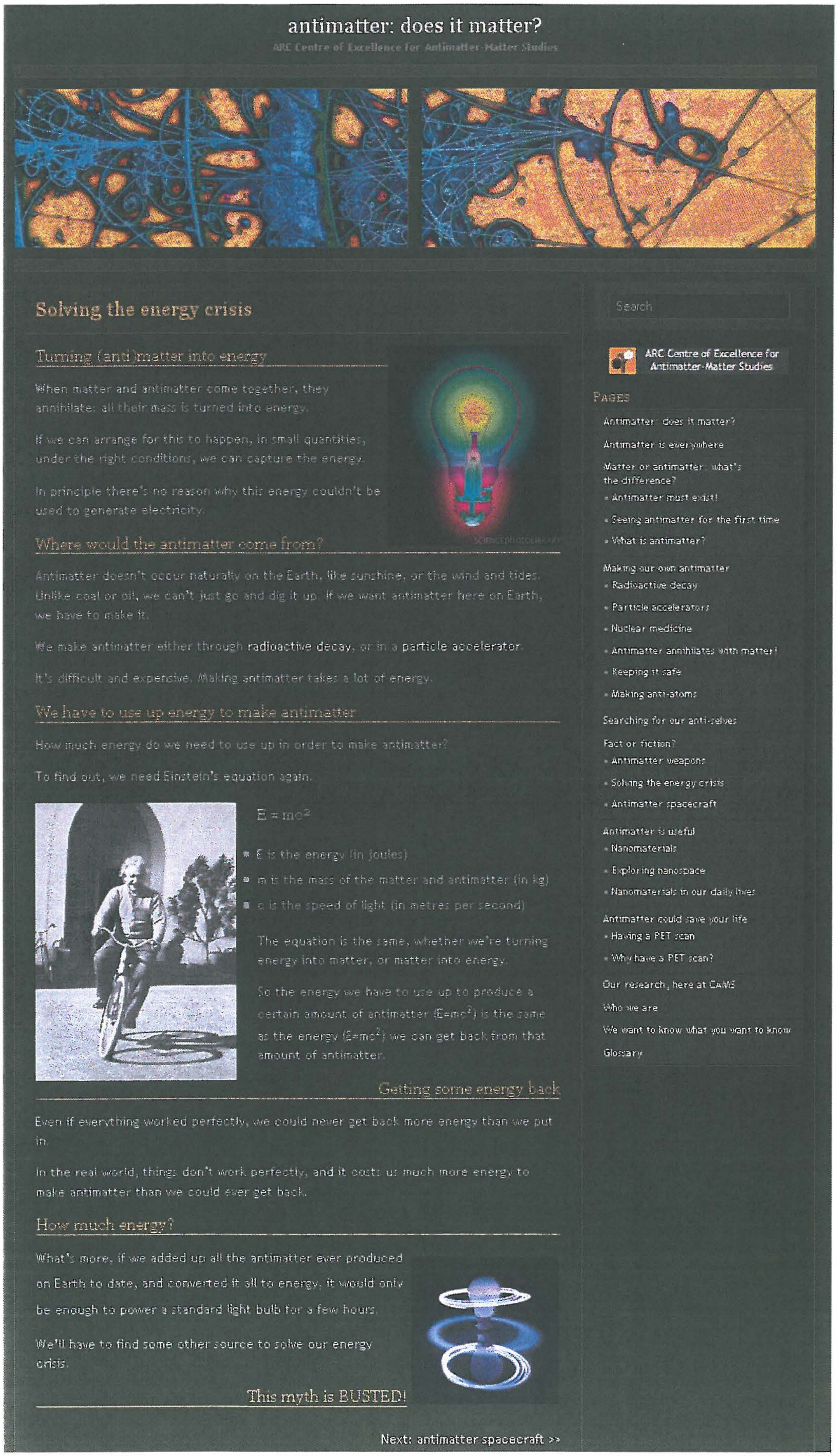
Four example pages from the website are shown below, for illustration.

Figure 3. Example page 1: Antimatter could save your life

Figure 4. Example page 2: Particle accelerators

Figure 5. Example page 3: Radioactive decay

Figure 6. Example page 4: Solving the energy crisis



antimatter: does it matter?

ARC Centre of Excellence for Antimatter-Matter Studies

Solving the energy crisis

Turning (anti)matter into energy

When matter and antimatter come together, they annihilate: all their mass is turned into energy.

If we can arrange for this to happen, in small quantities, under the right conditions, we can capture the energy.

In principle there's no reason why this energy couldn't be used to generate electricity.

Where would the antimatter come from?

Antimatter doesn't occur naturally on the Earth, like sunshine, or the wind and tides. Unlike coal or oil, we can't just go and dig it up. If we want antimatter here on Earth, we have to make it.

We make antimatter either through radioactive decay, or in a particle accelerator.

It's difficult and expensive. Making antimatter takes a lot of energy.

We have to use up energy to make antimatter

How much energy do we need to use up in order to make antimatter?

To find out, we need Einstein's equation again.

$E = mc^2$

- E is the energy (in joules)
- m is the mass of the matter and antimatter (in kg)
- c is the speed of light (in metres per second)

The equation is the same, whether we're turning energy into matter, or matter into energy.

So the energy we have to use up to produce a certain amount of antimatter ($E=mc^2$) is the same as the energy ($E=mc^2$) we can get back from that amount of antimatter.

Getting some energy back

Even if everything worked perfectly, we could never get back more energy than we put in.

In the real world, things don't work perfectly, and it costs us much more energy to make antimatter than we could ever get back.

How much energy?

What's more, if we added up all the antimatter ever produced on Earth to date, and converted it all to energy, it would only be enough to power a standard light bulb for a few hours.

We'll have to find some other source to solve our energy crisis.

This myth is BUSTED!

Next: antimatter spacecraft >>

Search

ARC Centre of Excellence for Antimatter-Matter Studies

PAGES

- Antimatter: does it matter?
- Antimatter is everywhere
- Matter or antimatter: what's the difference?
  - Antimatter must exist!
  - Seeing antimatter for the first time
  - What is antimatter?
- Making our own antimatter
  - Radioactive decay
  - Particle accelerators
  - Nuclear medicine
  - Antimatter annihilates with matter!
  - Keeping it safe
  - Making anti-atoms
- Searching for our anti-selves
- Fact or fiction?
  - Antimatter weapons
  - Solving the energy crisis
  - Antimatter spacecraft
- Antimatter is useful
  - Nanomaterials
  - Exploring nanospace
  - Nanomaterials in our daily lives
- Antimatter could save your life
  - Having a PET scan
  - Why have a PET scan?
- Our research, here at CAMS
- Who we are
- We want to know what you want to know
- Glossary

7.1.3 Viewing the artefact

The nature of modern websites is such that a DVD copy can often fail to represent their layout correctly. Where style sheets or other formatting data are stored separately from the site's content, it can be difficult or impossible to transfer this information accurately onto any more traditional medium. For this reason, no disc is supplied with this thesis.

The artefact can be seen at http://discover.positron.edu.au/.

7.2 Evaluation of the artefact

The purpose of the project was to construct a website which would inform the public about antimatter, taking into account the client's specific wishes and requirements, and with attention to the current best practices in science communication.

As discussed above, the evaluation process itself is beyond the scope of this project, but the artefact conforms to current thinking about effective science communication, and has been evaluated as a success by the client, since the website is now in use. I have recommended to the client various methods which could (and in my opinion, should) be used in the future to evaluate the audience's interactions with the site, and the site's suitability for its intended audience. (See "Audience feedback", page 79, and "Refining the communication material", page 80.)

8 Conclusions and recommendations

8.1 Limitations of the study

This thesis describes the construction of a commissioned artefact, designed and built to serve a practical purpose. It's only to be expected that there will be some natural tension between theoretical best practice, and the client's immediate requirements and preferences. A certain amount of compromise is therefore inevitable.

8.1.1 Audience feedback

The Deficit Model of science communication isn't necessarily the best model in every case. A website isn't as interactive as, for example, a question-and-answer session, and so is less immediately responsive to its audience's needs and interests. However, as the size of the audience increases, the question-and-answer model becomes unwieldy. It isn't a feasible model for a public Internet site. (Note that a website is still more interactive than a book, as feedback can be incorporated and selected questions can be answered quickly on the site, if the site's administrators choose to do so.)

For practical reasons, neither the Context Model nor the Dialogue Model of science communication was available to this project. Fortunately the online survey, and planned future evaluation of the communication, can serve to soften the "Deficit Model" nature of a largely one-way educational resource.

8.1.2 Choice of medium

A website isn't the only means of reaching the public, and the choice of a website to communicate fairly complex scientific material might, even today, be seen as preaching to the converted. In the USA (and by extrapolation the developed world) there is evidence that the most technologically-literate sectors of society (in other words those most likely to have, and make use of, Internet access) will already be the best informed about science (American National Science Board & American National Science Foundation, 2002, p. 31 of Chapter 07). However, this is less significant every day, as more and more of the population goes online.

A website is only ever as good as the people who maintain it. It has to be updated regularly, in order to retain its existing audience and to establish credence with new visitors. It has to be tested regularly, and in detail, with the latest versions of all popular browsers and operating systems. On the subject of a website belonging to the CERN Outreach Project, Professor Frank Close of the Department of Theoretical Physics at the University of Oxford says:

> A web site, especially one such as we are describing, is a complicated signpost like a signpost in the woods promising interesting places 2 km away. However, there is no guarantee that the pathway is still open and not overgrown; and if you do reach your goal, the site may be in ruins. This is a familiar experience on the web. (Close, 2002)

A few of CAMS' peer organisations have public outreach websites which show signs of just such neglect. (See A best-practice review of online public outreach by the client's peer organisations, page 56.)

8.2 Limitations of the methods

"The public" represents an enormous range in interests and education levels, and creating an artefact to appeal to the entire population is almost impossible. Under these circumstances, one practical approach is to include sections that uninterested readers can choose to skip, either because the "optional" material is too complex, or because it explains something that the reader already understands. The explanation of scientific notation, and the description of a cloud chamber, are illustrations of this approach.

It wasn't feasible to survey a representative sample of the public, and therefore only very limited feedback has been obtained so far. I've drafted, and suggested including, a feedback section on the site, so it will be possible to evaluate its effectiveness in the future.

This version of the website can be considered (if the client chooses) as a first draft. It's designed to be self-evaluating, so that as readers respond to the survey or submit questions, the material can be better tailored to their requirements.

8.3 Future projects

8.3.1 Refining the communication material

The web-based communication material could have been better tailored to its intended audience, had it been practicable to conduct a larger-scale, more-detailed survey beforehand. In particular it would have been useful to survey a representative audience in advance about what they already knew, what they would like to learn, and how they would like to learn it. To compensate for this, the site includes an online survey, so it will be possible to refine the content in future. Paying close attention to the feedback and survey section of the website will allow CAMS to refine the site's content.

CAMS also intends to continue performing the public lecture, for a variety of audiences. Whenever the lecture can be given to a more representative, genuinely "public" audience, it will be possible to run the existing survey again, and once enough responses to this survey have been obtained, they can be tabulated and used to produce a more detailed survey. This detailed survey can be used at future lectures, and incorporated into the website, to construct a more accurate idea of the audience's existing knowledge, beliefs and interests.

This iterative process can be used to refine the content of the lecture, website and future surveys for as long as CAMS wishes the various projects to continue.

8.3.2 Adding further communication material

I have suggested to the client a few more instances where animated diagrams would be beneficial. In addition to these, it would be possible to identify (through a more detailed survey) the topics which readers found most difficult to comprehend, and address these with animation, or more interactive multimedia.

8.3.3 Attracting more visitors to the site

CAMS could identify and approach popular science websites which might provide mutual links to the CAMS website. This would not only provide visitors to the CAMS site directly from the other sites, but would also help to raise the prominence of the CAMS site with various search engines. According to Allen:

> The world's science websites are not in any formal network as such but they share a common interest, and in many ways the science culture of connecting ideas. If you have built a website which adds to the world's pool of science communication resources, you should make a point of alerting other science sites. There's a very high likelihood they will include you in their link list. (Allen, 2001, pp. 184-185)

Similarly, CAMS could identify and approach educational websites, for example other universities and research establishments such as CERN. Mutual links to CAMS' website could provide the same benefits as above.

It might also be possible to identify other strategies used by search engines, to increase hits.

8.3.4 Monitoring traffic on the site

CAMS could install software such as Webtrends or Google Analytics, to monitor traffic. Noting which pages get the most hits, and readers' browsing patterns, could be a quick and efficient means of gauging visitors' interest in the various topics.

8.3.5 Preaching to the unconverted

The public lectures were advertised outside the science community, and according to the organisers many non-scientists attended the talks in Belgrade and Adelaide. However, at the talks where data could be collected, the overwhelming majority of the audience was made up of scientists and science students. It would be useful to conduct a survey to discover why members of the wider community didn't attend. Were they unaware of the talk? Was the talk advertised in the wrong media, or did our desired audience fail to notice the advertisements? If the advertisements were a success, and people were aware that the talk was to take place, did they feel that antimatter would be incomprehensible, or of no interest? Or did they feel they would not be welcome at a talk held in a university?

These findings would be relevant not just to future talks, but also to the publicising and future content of the website.

8.3.6 In-depth evaluation of the communication

This thesis deals with the creation of a science communication artefact, and I have suggested to the client an iterative process through which the artefact can be refined, as its readers' interests and understanding become clearer. As mentioned above, detailed evaluation of the communication is beyond the scope of this project. However, evaluation is vital. Without it, we cannot be sure that any communication has occurred. Sless and Shrensky describe exactly this situation:

> Just as the fact of performing a rainmaking ceremony is taken as evidence of the process at work, so the very act of doing and making – producing the annual report, the web site, the exhibit or whatever - is considered sufficient evidence of the process of communication at work. Indeed, many practitioners

> would see the completion of the message as the completion of the work. Exhibitors get paid to create an exhibition, writers get paid to write, and so on. The visitor's experience or the reader's understanding is either taken for granted, or part of someone else's responsibility. (Sless & Shrensky, 2001, p. 101)

This project has created an artefact which the client and I believe will be of interest and relevance to the public. I strongly recommend the instigation, in the not too distant future, of a complementary project to perform a detailed evaluation, and thus complete the process.

9 Appendix: CAMS audience survey

1. Was the technical level of the talk:
   - Too complicated?
   - About right?
   - Too simple?
2. Can you name something you learnt? ______________________________
3. Can you name something in the talk which surprised you? ______________________________
4. What did you like most? ______________________________
5. What did you like least? ______________________________
6. What would you have liked to hear more about? ______________________________
7. Can you think of something we could do to improve this talk? ______________________________
8. Was the talk what you were expecting? If not, what did you expect? ______________________________
9. How did you hear about this talk?
   - Radio
   - Newspaper article
   - University website
   - TV
   - Newspaper advert
   - School

   Other (please specify) ______________________________
10. Have you studied physics or any other science?

PHYSICS	OTHER SCIENCE
Physics at school to age 16	Science at school to age 16
Physics at school to age 18	Science at school to age 18
Undergraduate physics at university	Undergraduate science at university
Postgraduate physics at university	Postgraduate science at university
Evening class in physics	Evening class in science
Other (please specify) __________	Other (please specify) __________
How many years ago was that? _____	How many years ago was that? _____

Thank you!

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